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[illegible] experiences of some of their [illegible] his request, but a number [illegible] as special work of theirs [illegible] attempt was not mere [illegible] sincerely the gentlemen [illegible] salient portions of their [illegible] his own.

[illegible]-Steel Engineering Com- [illegible] bridge engineer and as the [illegible] put upon the market, wrote

[illegible]

[illegible] my experience which is worth re- [illegible] engineer for a bridge across [illegible] Boston Bridge Works were con- [illegible] subcontractors for the sub- [illegible] concrete. The bridge consisted [illegible] of the same length. The pivot [illegible] at the centre; and each of the [illegible] had a 24-foot roadway and one

[illegible] would be found, we were surprised [illegible] found a bed of small [illegible] This kind of foundation was not considered [illegible] the difficulty was overcome by converting this [illegible] the caissons having a much larger area. The piers [illegible] compressed air, and the following course was adopted. The [illegible] about 4 feet of water came in. This body of water [illegible] was converted into a rich grout. The [illegible] grout was sent down into the foundation, and the [illegible] It was found that this concrete spread out [illegible] in all directions, for in grouting the second tube of any pier [illegible] the grout used in the first tube had extended that far, so that [illegible] less grout than the first.

[illegible] was followed for all the tubes, including those for the pivot pier [illegible] that the foundation was converted into a mass of concrete, [illegible]

[illegible] method can be followed very readily when compressed air is used, but [illegible] when it is not used."

[illegible] expedient of Mr. Thacher's was truly a novel one and well [illegible] of record but also of adoption under similar condition[illegible] would be well to use it for all pneumatic piers that are not car[illegible] bed-rock and which rest on material into which grouting can be [illegible]

The late Horace E. Horton, Esq., C.E., who for many years w[illegible] of America's most prominent contractors, especially in highway b[illegible] work, wrote as follows:

"I have in mind the doubling up, in fact even trebling up, of old spans as w[illegible] girders to fit the increased loading (a continuous performance of railroad demand[illegible] have a case in mind of three 80′ spans—3-truss, double-track, half-through bri[illegible] which were re-erected as one single-track, 3-truss, 80′ span deck bridge, and [illegible] 6-truss, single-track, 80′ span deck bridge. This is as an extreme example and, [illegible] with three times the material to do the work it seemed desirable to add rivets at ce[illegible] points.

"I am disposed to question whether reminiscences of this class would have any [illegible]ticular value. They surely are interesting as showing the extreme of economy in [illegible] up old material.

"We have on repeated occasions reduced a double-track bridge to a single-track [illegible] cutting off the beams and using four stringers for a single track. We have rearr[illegible] two single-track-span deck bridges into one span. We have made two single[illegible] spans from three-single-track, deck-bridge spans. We have formed two single[illegible] spans into a single-span through bridge, using equalizers for floor connections to the[illegible] spans, and have riveted one track stringer immediately on top of another.

"I am not speaking of the above as a matter of novelty or merit, merely fact[illegible] the business presented itself in these shapes, which I presume it has done to all [illegible] manufacturing concerns in our line."

The eminent bridge engineer, Ralph Modjeski, Esq., wrote thus:

"Regarding expedients. At this time I can only mention a few which occur t[illegible] as follows:

Addition,

which do not
that has caused the writer the
girders and under short train

details of design, advised that
the bearing of the sole plates
the loading into a cast base
for our long girders from 70′

where the bridge pointed nearly North
one piece for the whole width of pier,
walls on abutments, we have had no
we have had several bridges which
stones on the abutments or on
caused by the girders sliding on the
for structures of this kind, using
shaped rocker or disc. These

necessity for a lot of steel castings and

---

‡ See Fig. 45c.

Civil Engineers.

[illegible] involved, and the [illegible] had [illegible] so as to keep them in line on this [illegible]

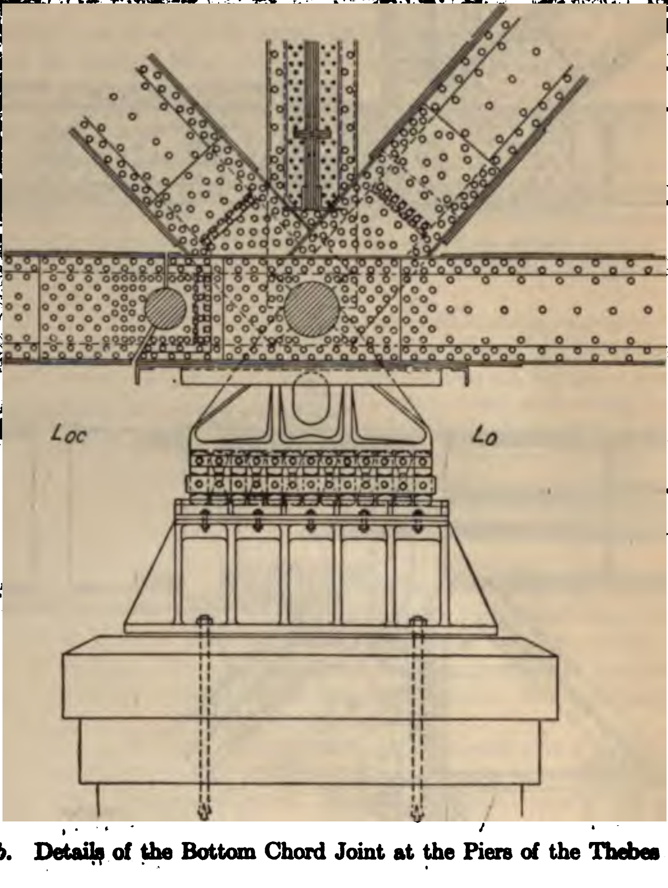


FIG. 45b. Details of the Bottom Chord Joint at the Piers of the Thebes Bri

Hodge had the courage to break away from the established prece The practically parallel diagonals of the trusses in the long spans o St. Louis Free Bridge certainly add greatly to the appearance o structure.

Mr. Hodge's detail for connection of end lower laterals is a good When hearing about it for the first time, one might be inclined to t that it involves weakness by putting bending moment on the end beams; but such is not the case, for the bringing together of th end laterals gives them the function of end chord members of the horiz lateral truss, thus cutting out the end panels of the bottom chords aiding to form the said truss. The great advantage of this deta

bridges, is an expedient worthy
of work will be found in the

1907, there is illustrated a most
curved in plan so as to
In the author's opinion,
for, as pony trusses were used,
on that kind of a truss, even
it appears like an unnecessary
condition by curving the top
the illustrations to be none
there is being entirely on the
Austerlitz Bridge over the Seine
stresses in this peculiar type
French Engineer, Monsieur Jean
hence it is not at all likely
computations; nevertheless an

bridge specialist when looking for the first time at either in *Engineering News* or the actual structure itself can feeling that he himself has been given an actual torsional expedient was employed many years ago by the late C. S in the Lachine Bridge, a single-track railway structure over Lawrence River near Montreal, by which the main span was erected as a cantilever for the dead load and after connection at middle was used as a continuous girder for the live load. The while novel, was not altogether satisfactory, mainly, perhaps, bec

Fig. 45c. Lowering a Caisson from Barges on the Broadway Bridge over the Wil River, at Portland, Ore.

continuous girders cannot be classed as truly scientific construction the experiment has not since been repeated. However, the bridge its work satisfactorily for more than two decades, and has only been removed so as to make room for a double-track structure.

The Union Bridge and Construction Company when erecting a bridge over the Atchafalaya River, where the water was very deep the current quite swift, employed a neat expedient by setting up turntable on the pivot pier, erecting thereon the tower, and cantilev out the trusses, one panel at a time. As the erection was done fr single large barge anchored in the stream, it was necessary to rotat partially completed superstructure after unbalancing it by a single length of steel. In this way it was obligatory to swing the work hundred and eighty degrees after the erection of each two panels.

scheme worked to perfection, and the span was completed quickly and without giving any trouble, the barge being moved laterally by the anchor cables as the arms were lengthened.

In *Engineering News* of May 12, 1904, there is described and illustrated a novel expedient for a skew crossing of a canal by running the track through a panel of a truss and depending upon the strength and stiffness of the chord to compensate for the missing diagonal. While the result was apparently satisfactory, the policy of the scheme is doubtful, because a better solution of the problem could have been obtained by the expenditure of more money. It appears, though, that the extra money was not available.

In *Engineering Record,* Vol. 53, p. 712, there is described a temporary wooden drawbridge over the Chicago River, one end being pivoted and the other resting on a scow, which was moved in the arc of a circle to open the draw. A somewhat similar idea is described in *Engineering News,* Vol. 50, p. 372. It consists of a draw span pivoted at one end and supported at the other by a bent resting on rollers running on a curved rail in the bed of the canal, the operation being effected by electric motors.

In *Engineering News,* Vol. 28, p. 441, there is a description of an ingenious way of saving a little money in the construction of a swing span by cantilevering out the ends of the approach spans so as to cheapen the piers, but the author is of the opinion that in most cases the cost of caring for the reversing stresses in the two anchor spans would more than offset the saving in the substructure, unless the pitch of the bed-rock on both sides toward the centre were unusually abrupt—a very rare condition. Another type of bridge, for instance a vertical lift, would have solved the problem much better.

The expedients which follow are some that have been evolved by the author.

In the design of the temporary bridge across the Missouri River at East Omaha, as mentioned in another chapter, the layout was made on a skew of eleven degrees so that later, when the remainder of the permanent construction was being built, all the new piers could be put in and all the new spans could be erected without stopping traffic at all on the old structure, of which only the pivot pier and the swing span were of permanent construction. Ten years afterward it all worked out as it had been arranged for in the beginning.

Another expedient in that structure was, for the sake of economy, to omit temporarily the cantilever brackets for the wagonways and footwalks and to place a single track at the middle of the bridge and operate it and the highway traffic on the same space until business conditions should demand a better arrangement.

The method described in Chapter XLI for righting two of the piers of the permanent construction of the East Omaha Bridge by means of wire ropes with a toggle between was an expedient of value. The author

employed it again a few years afterward for righting the east rest pier of the Sioux City Bridge, which had been moved out of plumb by a land slide that was caused by the piling of a great mass of rock on the bank just under the approach.

The patented arrangement, mentioned elsewhere herein, for building long span bridges at first for single-track, and later by duplicating the trusses alongside and putting in extra lines of stringers to provide for carrying a double-track, is an expedient that, under certain conditions, it may prove advisable to adopt, as it might save the interest over a long term of years on thirty or more per cent of the first cost of constructing a double-track bridge.

The design described in Chapter XL for building a crib and caisson so that it may be sunk part way by the pneumatic process and the remainder by open dredging is an expedient that ought to be very useful in bridging near their mouths some of the rivers that discharge through delta-lands into the Gulf of Mexico, and for crossings at other places where similar conditions exist.

In order to anticipate the possibility of a sliding of the banks into the channel of the river and thus overturning or otherwise disturbing the piers of a certain single-track railway bridge, the author designed each of the shore piers as a single cylinder large enough to accommodate the shoes of the trusses, and made the bases of all the channel piers octagonal with the noses of the octagon pointing longitudinally with the bridge so as to cut into the loose sliding earth and turn it aside. He counted upon carrying the piers by open dredging some one hundred and forty feet or more below water, well into a layer of coarse sand that underlay the softer material. His plan was rejected after bids were called for because of its claimed high cost, and ordinary pneumatic piers of timber construction with their long sides up-and-down stream were built and carried down to the safe working limit for compressed air, viz., about one hundred and ten feet below the water level, which was then at or near its extreme height. In spite of vigorous protests by the author, both verbal and written, this policy was adhered to with the result that the anticipated slide occurred before the bridge was completed, and one pier was toppled over to such an extent that it could not be righted. The result was a far greater expenditure of money than would have been necessary to build the substructure properly and safely according to the author's design. This case has been mentioned a second time in order to call attention to the expedient of designing so as to prepare for the contingency of a great lateral earth slide.

At the time it was built, the spread span of the New Westminster Bridge over the Fraser River, shown in Fig. 45*d*, was an expedient, although today it may be considered standard practice, as the idea has been adopted on several important constructions.

The method of semi-cantilevering evolved by the author, as described

in Chapter XXV, was at the time an expedient; but it also has since become standard practice.

The method of anchoring a large, light swing span to its pivot pier by means of a long bolt of great diameter running down into the masonry, as described in Chapter XXIV, is an expedient that ought to be adopted wherever the conditions demand the protection that such an anchorage would afford.

Fig. 45*d*. Spread Span of the New Westminster Bridge over the Fraser River in British Columbia.

In the building of the new Granville Street Bridge at Vancouver, British Columbia, alongside of the old one, which was at a considerably lower level, the two structures were so close together that it was necessary to cantilever one arm of the new swing span over the space occupied by one end of the old draw when it was being rotated—an expedient that worked quite satisfactorily.

In designing the scheme for the erection of the City Waterway Bridge at Tacoma, Washington, on the same line as that of the old bridge, but somewhat higher, it was necessary to maintain traffic. The author accomplished this by building a wooden trestle on the right-hand side of the city end and on the left hand side at the other end, carrying both trestles a little way out into the navigable channel and turning the swing span at a skew so as to connect with the two ends. As the new movable span was to be a vertical lift (see Figs. 31*n* and 31*o*) and a little shorter than the old swing, there was room to put in the new piers for the lift span close in front of the old rest piers of the swing. The old approaches

were then removed and the new ones were built, after which the lift span was constructed aloft on cantilevered falsework tied back to the finished construction; then the falsework was removed, the swing span was floated off, the lift was lowered for traffic, and the old piers were taken out.

In a design for a vertical lift bridge to cross the Second Narrows at Vancouver, British Columbia, in order to carry across it the pipes for the city's water supply, the author evolved an expedient for supporting them at a considerably lower level than the top of the towers, near which they ordinarily would have to go. The proposed structure was designed for a double-track railway between the trusses to carry both steam and electric trains and a roadway and footwalk on each side cantilevered beyond the trusses. He took advantage of this fact by building two shallow, narrow spans to carry the pipes inside and arranged to support them on brackets cantilevered out from the front vertical posts of the tower and braced back diagonally to the rear inclined columns thereof. The movable span at its highest possible position brought the sidewalk flooring within a foot of the pipe girders, the trusses of the said span passing through the rectangular space left between the opposite pipe-supporting spans.

In Bridge No. 9 of the Canadian Northern Pacific Railway across the Thompson River, the water was quite deep and the current swift at the narrow part of the stream, over which it was arranged to build a single through span. As the bottom was covered with large boulders, the author feared that it would be impracticable for the contractor to build, without going to unduly great expense, falsework that would withstand the current; consequently, in preparing the bidding specifications he suggested a means for erection that is worthy to be classed as an expedient. It was to build falsework out from each shore as far as practicable and to place in the intervening space three barges headed up-and-down stream and effectively braced together horizontally at their tops and carrying timber falsework braced substantially in vertical planes, and anchoring the combination diagonally by adjustable cables both above and below so that it could be kept in correct position at all times, even should the elevation of the water vary a foot or two, which was more than would be likely to occur during the erection season. The decks of the barges were to be a little higher above the water than would suffice to put the erected span at its final elevation. The erection was to be done by starting at mid-span and working at a uniform rate of progress in both directions, cantilevering the ends beyond the barge, and letting water into the latter to permit the completed metalwork to come to final position. As it turned out, however, the contractor was able to drive piles between the boulders and to maintain his falsework without going to as much expense as the flotation method would have involved.

The proposed cantilever bridge to cross the entrance channel to Havana Harbor, illustrated in Fig. 52*a*, contains several expedients worthy of mention, notably the spiral approach which the author evolved so as to at-

tain the required elevation in a very limited space. As far as he knows, this is the first occasion that the idea has been suggested for bridge construction. Again, the placing of a large amusement building or casino above the spiral stairway so as to make it the most popular resort in Havana may properly be termed an expedient, for it will utilize at comparatively small expense space that might otherwise have been wasted, the extra cost of the pedestals and columns for carrying the building being comparatively small. The suspension detail adopted for this bridge and which was described in Chapter XXV as having been evolved by the author for the new Quebec Bridge is still an expedient, for it has not yet been actually employed in construction. The hoisting of the suspended span by four wire ropes from barges to a height of nearly two hundred feet clear above the water as projected by the author is also an expedient. But the most unique expedient of them all in this proposed construction is the designing of the metalwork in such a way that, if it be knocked down by gun-fire from an enemy's fleet or by dynamiting, it will not entirely block the navigation of the harbor by its fall. It was necessary for the author to do this in order to overcome the opposition of both the War and the Navy Departments at Washington to the project. How this result was accomplished can be understood by a study of Fig. 45*e*, which shows what would occur were the superstructure cut at different places. This plan was accepted by the General Board of the Navy and by a special board of three Army Engineers appointed by the Secretary of War to investigate the matter. A curious piece of information was obtained during this investigation, which may be worthy of record. One of the members of the Army Board asked whether the shock resulting from the striking of the cut end of the suspended span against the bed of the channel would not cause such a great reaction at the support as to break the metal there and let the span fall entirely. The author assured the Board that it would not; and in order to prove the correctness of his claim, he retained his brother-in-law, A. McL. Hawks, Esq., C.E., to make some experiments by dropping one end of a cast iron bar suspended at the other end from a large spring scale, and recording the readings of the scale, the ratio of length of bar to fall being the same as that of the length of span to its height above the channel bed. Much to the surprise of all those interested in making the experiment, the reading reduced immediately to nearly zero and then went for an instant to nearly the total weight of the beam and finally to about one half of the said weight. The apparatus was crude and the readings were not well recorded; but the experiment was repeated a number of times with approximately the same results. Had the apparatus been perfect, it is likely that it would have shown a zero reading during the fall, one of double the static reading of the suspended beam immediately after the shock, and that found by applying the law of the lever after the bar had come to rest. Based upon this experiment, the author reported to both Boards

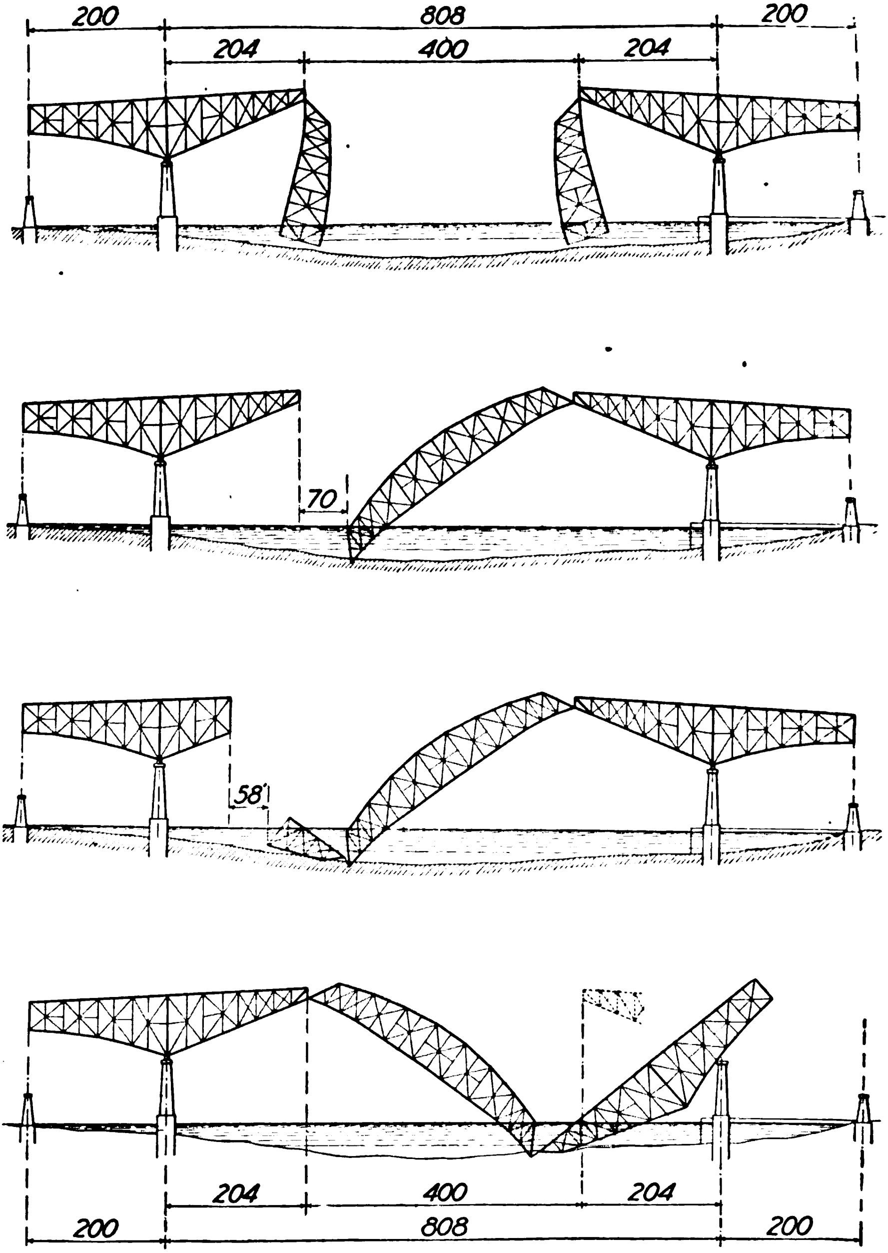


FIG. 45e. Methods of Failure of the Proposed Havana Harbor Bridge if Struck by Gun-fire.

that the worst possible result of the shock would be to double the dead load reaction at the support, making it about the same as the greatest reaction there from combined dead load, live load, and impact, and showing conclusively that the effect of the jar could not possibly bring down the other end of the span. Meanwhile, however, the Army Board had reported favorably on the author's plan submitted, having accepted his assurance that the support would carry safely the dead load under the most adverse circumstances; but the confirmation offered by the experiment was most satisfactory to all concerned.

The author's latest expedient is one evolved in connection with the Ohio Avenue Bridge over the Kaw River in Kansas City, Kans., which structure was most unjustly condemned by the Drainage Board as being an obstruction to the flow of the current. It consists of three riveted spans, one of which was previously described herein and illustrated partially in Fig. 1*h*. These spans are in excellent condition; but, owing to strong pressure brought to bear on the railroad company by numerous business patrons who have been induced to believe in the erroneous statements of the Drainage Board, that company has agreed to remove and possibly to replace its structure. To do this to best advantage the author suggested the utilization of all three of the old spans by converting the bridge into a cantilever structure, as shown in Fig. 45*f*, lengthening it from six hundred feet to eight hundred and forty-four feet in order to conform to the increased width of river established by the Drainage Board and to the increased skew, the existing structure crossing at an angle of about twenty degrees and the new one at about twenty-seven degrees. The increase was adopted in order that the sharpest allowable curve (fifteen degrees) on the west embankment might not encroach on the right-of-way of another railroad. The tops of the main posts of the cantilever arms are to be tied back to the end pins of the anchor arms by means of eyebars; and suitable anchorages will have to be built to take care of the uplifts that these backstays produce. The only members of the anchor arms that will have to be modified to meet the new conditions of stress are the bottom chords, which will have to take compression from end to end, and also, in certain panels, alternating compression and tension.

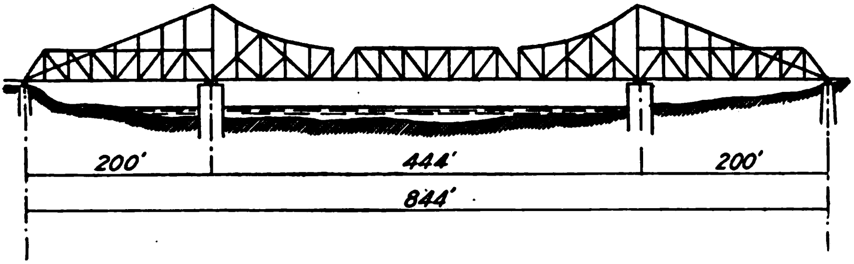


FIG. 45*f*. Simple Span Bridge Converted into a Cantilever Structure.

The author had figured on employing Mayarí steel, or some other alloy of like capacity, for the principal members of the cantilever arms in order to reduce the uplifts as much as practicable, and the same alloy in the new members of the bottom chords of the anchor arms so as to avoid the adoption of unduly large sectional areas. The excess price quoted for the finished Mayarí steel work was only eight-tenths of a cent per pound as compared with carbon steelwork. The estimated cost of the repaired bridge is about sixty per cent of that of a new structure of the same carrying capacity.

ADDENDUM

After the plans for this reconstruction were partially completed, it was found necessary to abandon the scheme, because of excessively high property damages that were claimed by the land owners whose holdings would have been crossed by the new line.

CHAPTER XLVI

DATA REQUIRED FOR DESIGNING BRIDGES, TRESTLES, AND VIADUCTS

The importance of a thorough preliminary study of all the conditions that can possibly affect the designing of a structure cannot well be over-estimated. Too often designs are made from insufficient data, with the result that changes in plans become necessary as the work progresses; and such changes are very expensive in many ways.

First. They cause delay—and time is money.

Second. They involve the discarding of work already done, and that work costs money.

Third. Modifications in construction are costly, *per se*, for remodeling is slow and expensive work.

Fourth. Notwithstanding the fact that the specifications and contract usually provide for the contingency of making changes and determine upon a method of payment for them, nevertheless it is true that alterations of every kind are nearly always a source of unusually large profit to the contractor. One reason for this is that changes are a legitimate excuse for delay, and as the company is generally in a hurry for its structure the contractor has to be persuaded to make special effort to hasten completion. The most common means of persuasion is offering additional compensation.

Fifth. The making of important changes in the plans is a good and sufficient reason for either extending the time set for completion or for cancelling entirely the clause in the contract relating to that subject. In dealing with the contractor concerning modifications in plans and construction, it is always best to have made and signed a supplementary contract covering in detail not only the changes themselves but also the extent to which they shall affect the time of completion of structure.

Sixth. But, worst of all, it is held by many lawyers that any fundamental change in the work will render the bond null and void; consequently, if this view be correct, in case that the contractor throws up the contract the company will have no redress, but will have to take his plant, pay all of his outstanding bills for labor and materials, and complete the construction by either administration or the letting of a new contract. In effecting a final settlement with the contractor by legal process the fact that changes in the construction were made by the company will generally militate heavily against the latter, especially if the trial be by jury—that relic of barbarism which enlightened nations seem unable to cast aside.

In view of all these objections to changes being made in plans after the contract is let, is it not evident that any money spent legitimately upon the preliminary investigations is money well expended? Nevertheless, one of the most difficult tasks that the consulting engineer encounters is the persuading of his clients to provide the necessary money for such preliminary investigations. Under ordinary conditions one should be able to prove convincingly the necessity of making sufficient borings to determine beyond the peradventure of a doubt the location of bed-rock and the character of the overlying soil, or the desirability of surveys or other investigations to find the greatest volume of water that will pass the cross-section in a given time; but when it comes to unusual conditions, such as the inception of work of a novel character, it is hard to persuade the promoter that it is advisable to spend money to learn how best to design and construct the work, for he thinks that the engineer ought to know such things without investigating; and it is not unusual for a promoter to remark to the consulting engineer, "I am paying you a big fee for your special knowledge, and, in addition, you want me to spend a lot of money to teach you things that you ought to know but don't." On one occasion the author nearly lost the engineering on some four million dollars' worth of elevated railroad work by requesting permission from the President to spend three or four thousand dollars on some special studies and estimates. The result of the expenditure, however, was the immediate saving of more than one hundred and fifty thousand dollars.

In order to facilitate the professional work of his firm the author some years ago prepared a little pamphlet for distribution to clients and to those who request information concerning the cost of bridges. It is entitled "List of Data Required for the Proper Designing of Railroad Bridges and Trestles," and is reproduced here *verbatim*, including the prefatory remarks.

"The following lists of data required to make the best and most economic designs for railway bridges and other structures have been prepared by us to submit to our clients in various countries, spaces being left for writing in the information. For any particular crossing, of course, it is not necessary to collect all the data called for on the list; but the more preliminary information concerning the conditions that is secured, the more perfect and economical will be the design made.

"The objection is sometimes raised that the collection of so much information is expensive. It certainly is; nevertheless it is in every way compatible with true economy.

"The collection of the data can either be done by the railroad company through its engineers, or it can be entrusted entirely to the bridge specialist who is to prepare the plans and specifications. For large bridges and for a group of small ones it is best to let the specialist do this preliminary work; but for a small bridge or two only, it will generally be advisable on the score of economy to have the railroad engineers collect the data.

"BRIDGES

"1st. Profile of crossing on which should be located the following: (Elevations can be written in below, calling the elevation of base of rail at mid-length one thousand.)

a. High water mark (extreme)..............................

....

b. Low water mark (extreme)..
....

c. Bottom of channel or mud line....................................
....

d. Bed-rock, if any, with overlying strata. (Describe fully the soil, and give approximately its bearing capacity)..........................
....
....
....
....

e. Grade line on structure, *i. e.*, the elevations of base of rail. If structure is to be on curve, indicate the compensation, if any.................
....
....

f. Kinds of approaches, whether of steel viaduct, earth embankment, or timber trestle ....
....

Profile should be made to scale, and the scale of drawing should be indicated thereon.

2nd. Any restrictions that there may be concerning the following:

a. Location of piers...
....
....

b. Lengths of spans...
....
....

c. Overhead clearance beneath structure............................
....
....

d. Shore protection...
....
....
....

e. Channel booms or guides..
....
....
....

3rd. Clearance between trusses, number of tracks structure is to carry, distance from centre to centre of same, and gauge of railroad.....................
....
....

4th. Vertical clearance above base of rail, also horizontal clearances near the deck...
....

5th. Style of floor, whether of timber ties, ballast, or solid steel. Is the structure to provide for highway traffic; and, if so, of what kinds? How many lines of stringers per track are to be adopted? Make sketch of floor, and give sections, locations, and heights of track rails and guard rails. State whether snow plows are used on the road. Is the floor timber to be creosoted or otherwise treated?
....
....
....
....
....

6th. Widths of sidewalks, if any are required..

....

7th. Live loads for spans.

a. Maximum weight of engine and tender; make sketch showing wheel spacing and load on each axle, or else adopt some standard loading.

....

....

b. Maximum weight of cars fully loaded and wheel base of the same; also weight per foot of loaded cars...

....

c. Highway live loads, if any. (Preferably adopt one or more of those given in some standard specification)...............................

....

....

8th. State whether stream is navigable, and, if so, what clear height will be required beneath structure; also what clear distances will be required between piers?

....

....

9th. Is stream subject to sudden rises and rapid currents, and at what seasons of the year?...

....

10th. Does stream carry much drift?...

....

11th. Is there any danger of the channel changing? State fully the liability to scour...

....

....

12th. State the cost in U. S. gold dollars of the following delivered at bridge site:

a. Portland cement, per bbl...

....

b. Broken stone and gravel, per cu. yd..

....

c. First-class masonry stone, per cu. yd...

....

d. Sand (clean, sharp, and coarse), per cu. yd.....................................

....

e. Transferring steel work from cars or vessel to bridge site, per lb.......

....

f. Timber for flooring, per M. ft. B. M...

....

g. Timber for falsework, per M. ft. B. M..

....

h. Piles for falsework, per lin. ft...

....

i. Labor per day...

....

j. Treatment of timber, per M. ft. B. M...

....

13th. Map showing location of bridge, including stream for at least half a mile each way from bridge site. (For unimportant streams and those not navigable this will not be required.) Give scale of map...

....

....

....

14th. Is structure on tangent or curve? If on curve, give degree of curvature, or angles of skew, and show same on map. Is curve to be eased? Show beginning and end of curve..

....

....

15th. Is structure square or on a skew? If the latter, give angle of skew and make a sketch..

16th. Area drained by opening, if it has been measured or estimated, together with such a description of the watershed as will enable one to determine what constants to use in the formulæ for flow. Instead of this may be given the measured or estimated cross-section and velocities of stream at high water............

....

....

....

....

....

17th. When the stream is navigable and a low bridge is required, some style of movable span must be used; hence, to aid in selecting the proper type of structure, please answer the following:

a. Will a centre pivot pier be permissible, and, if so, what clearances will be required between it and the two end piers?..........................

....

....

b. If a centre pivot pier cannot be used, what clear waterway will be required between end piers of lift-bridge, measuring at right angles to the direction of the channel?..

....

c. What clear height will be required beneath structure for the passage of vessels?..

....

d. State minimum time in which it will be necessary to open draw span or raise lift span to full height..

....

e. Will electricity for operating the span be obtainable from any existing plants at a reasonable price?...

....

f. About what would be the probable maximum number of times the span would have to be opened or raised in 24 hours?................................

....

g. Dock lines should be indicated clearly on both the plan and the profile, also the exact angles they make with the centre line of bridge and with the centre line of clear channel required.....................................

....

....

18th. Any other data not herein mentioned, which may prove useful in making the design..

....

....

....

....

....

....

....

....

"STEEL RAILWAY TRESTLES, VIADUCTS, AND ELEVATED RAILROADS

1st. Profile on centre line of structure, on which should be indicated the following: (Elevations can be written in below, calling the elevation of base of rail at mid-length one thousand.)

a. Ground line..
....

b. Bed-rock, if any, with overlying strata. (Describe fully the soil and give approximately its bearing capacity)..................
....
....
....

c. Grade line on structure or required elevations of base of rail. If structure is to be on curve, indicate the compensation, if any............
....
....

d. Kinds of approaches..
....

e. Cross-sections of ground every 30 feet or 40 feet, extending at least 30 feet on each side of centre line of structure, and, on irregular ground, a contour map with horizontal sections from two (2) to five (5) feet apart vertically..
....
....
....

f. High water mark, if any..
....

Profile should be made to scale, and the scale of drawing should be indicated thereon.

2nd. Any restrictions that there may be concerning the following:

a. Location of pedestals and abutments..................................
....
....

b. Lengths of spans...
....
....

c. Overhead clearance beneath structure.................................
....
....

d. May longitudinal bracing be used, and, if so, with what restrictions?....
....

e. Is it permissible to carry the transverse sway-bracing to the ground, or must an unobstructed space be left longitudinally beneath the structure?
....

3d. Number and spacing of tracks and gauge of railroad. State whether structure is to carry also highway traffic, and, if so, what kinds......................
....
....
....

4th. Style of floor, whether of timber, reinforced concrete, buckled plate, or asphaltum and concrete on buckled plate. Make sketch of floor................
....
....

5th. Widths of sidewalks, if any be required................................
....

6th. Live load. (See Bridges.)

7th. State fully the cost in U. S. gold dollars of the following at site: (See Bridges.)

8th. Plan of crossing showing degrees of curvature, if any, angles of skew, easements, points of curve, etc.

9th. If in a city or town, show streets, alleys, building lines, curbs, etc., crossed or affected in any way by the structure; and show where columns are to be located, whether in street or on sidewalks near curbs, giving exact locations for all special cases..

....

....

10th. If any tracks or other obstacles are to be spanned, locate them exactly and give clearances required, both vertical and horizontal..........................

....

....

11th. Indicate on profile and plan where steel trestle is to begin and end..........

....

....

12th. Any other data not herein mentioned, which may prove useful in making the design"..

....

....

....

....

....

....

....

....

....

....

Captious readers of this chapter may make the comment that the preceding lists are altogether too detailed for the purpose of designing bridges, for while such minor matters as the cost of cement, sand, gravel, stone, hauling, etc., would certainly affect the total cost of a structure, they cannot influence its design. To such readers the author would state that in certain cases even such a small thing as the cost per barrel of cement at site would change the layout of spans from that which would ordinarily be adopted. For instance, in one of his bridges the cement at site was worth eighteen dollars per barrel. Is it not evident that for such a location the quantity of concrete used should be reduced to a minimum and that cut stone masonry should be adopted instead? Again, in building bridges in mountainous districts, the metal work for the superstructure has sometimes had to be carried or dragged from the railroad or seaport by burros. Would not this circumstance affect greatly the designing of the individual members of the superstructure? In collecting data for the designing of bridges no condition is too trivial or too unimportant to be worthy of noting, and the important conditions should always be investigated with the utmost thoroughness, regardless of how much the investigation may cost.

CHAPTER XLVII

LOCATING OF BRIDGES AND PRELIMINARY SURVEYS

For small bridges and culverts, the location is determined by the alignment of the road. Usually this is fixed by conditions which are beyond the influence of the needs of the smaller crossings; and hence it governs their location largely, if not entirely. But where the crossing is of sufficient magnitude and importance to influence the location of the line, a careful study of the physical conditions by a reconnaissance covering a number of possible sites should be made, in order to secure the best and most economical crossing possible. That layout should be selected which is the best in respect to the following particulars:

1. Permanency of channel.
2. Narrowness of channel.
3. Large average depth of water relative to the maximum depth.
4. Straight reach of river for several miles. especially if draw-spans are contemplated in the layout.
5. Freedom from islands or other obstructions that might disturb or deflect the current.
6. Remoteness from sharp bends.
7. Presence of high banks.
8. Possibility of crossing at right angles to axis of stream.
9. Absence of curves in both approaches to the bridge or upon the structure itself.
10. Absence of sag in grade on structure.
11. Economy, which involves the following considerations, in addition to those already given,
    - *a.* Depths of pier foundations.
    - *b.* Materials to be excavated for substructure.
    - *c.* Quality of the foundation material.
    - *d.* Force of current during high water.
    - *e.* Height of piers.
    - *f.* Cost of protection work and of its maintenance.

One of the most important features affecting the layout of a bridge is the permanency of channel. With a shifting channel a longer bridge must be provided to meet the vagaries of the river, and sometimes it is necessary to construct two draw spans in order to meet navigation requirements. Examples of this case are the author's bridges over the Missouri River at Sioux City and East Omaha. A better appreciation

of the conditions which promote permanency of channel will follow from the study of the general action of rivers. This is essentially a consideration of the continuous readjustment between two contending factors in an effort to bring about an equilibrium—the water seeking a lower level and the resistance set up by the soil tending to retard its motion. A river receives the run-off from a definite, fixed drainage basin. This run-off in seeking a lower level follows the line of steepest declivity, and usually sets up such a velocity that scour results. The softer the material forming the channel, the more readily will scour occur. This scouring action forms bends in the channel which become accentuated until sufficient additional length has been introduced to decrease the slope to such an extent that the resulting velocity will no longer produce scour. The stream has then attained, for the time being, a condition of equilibrium or fixed regimen for a particular rate of discharge during which neither scouring nor silting takes place. It has been found from observations made on the rivers of India that for any section of channel and character of silt the critical velocity (at which neither scouring nor silting takes place) depends upon the depth and is given by the equation,

$$v_s = md^{0.64},$$

where v_s = the critical velocity in feet per second,
d = depth of channel in feet,
and m = a coefficient having values as follows:

Light sandy silt	0.82
Coarser but light sandy silt	0.90
Sandy loam	0.99
Coarse silt, such as débris of hard soils	1.07

But the run-off from the catchment area varies from time to time and a new velocity is produced, disturbing the pre-existing regimen; and then scouring or silting results until another approach is made toward equilibrium. The river, as a matter of fact, is in a constant state of readjustment, oscillating back and forth between a preponderance of scouring and of silting. It is true that these two actions go on simultaneously in different parts of the river, owing to whirls and cross currents. For example, the concave sides of the bends are being eroded, while the convex sides are being filled. Unless the banks of the stream are sufficiently stable to resist this scouring action, no permanency of channel can be expected without resorting to protection. In case of rivers the channels of which lie in flood plains of alluvial deposits flanked by bluffs of hard and more stable formations, such as the Missouri for example, the tendency is for the stream to oscillate from bluff to bluff, forming a series of bends, which exhibit a general, progressive shifting of channel location down the valley. Without protection works sufficient to fix the channel, it is a foregone conclusion that any bridge location on such a stream will sooner or later be menaced by this progressive down-stream movement.

[illegible] underlying the site, banks of gravel [illegible] formations involve favorable conditi[illegible] comparatively large ratios of area to wetted [illegible] A straight reach of the river is an [illegible] because the banks escape the direct impact [illegible] in consequence, less danger of erosion. [illegible] proper weight to the relative permanency of the c[illegible] affecting the location of a bridge site are next [illegible]

[illegible] is an advantage, as a shorter bridge [illegible]

[illegible] of a large average depth as compared with the [illegible] such a condition involves a more efficient discharge [illegible] liability to scour in flood time than will exist when the [illegible] depths is small.

When draw-spans are contemplated, a straight reach of the ri[illegible] necessary so as to provide sufficient room for permitting a boat a[illegible] tow to straighten out and to direct themselves squarely toward the [illegible] span before approaching dangerously near the bridge.

Freedom from obstructions in the stream, such as islands abov[illegible] bridge site, is desirable, because such obstructions deflect the [illegible] shoreward and increase the possibilities of an erosion that might [illegible] the river to cut in behind the bridge.

Remoteness from sharp bends, especially above the bridge [illegible] advantageous, because the erosive action of the current at such [illegible] receiving as they do the full impact of the water, is excessive. [illegible] is always in rivers with alluvial flood plains the danger that the [illegible] will cut in behind the bridge, unless effective protection work is in[illegible] The soundness of this statement is well illustrated by the difficu[illegible] has been experienced in protecting the railroad bridge across th[illegible] souri River near Blair, Nebraska. That structure is located abo[illegible] mile below a sharp, right-angled bend in the river, which bend, [illegible] is only two miles down stream from a still sharper bend in the [illegible] direction. The river has repeatedly tried to cut across and ha[illegible] prevented from so doing only by extensive bank protection. An [illegible] trated description of this protection work is given in the *Engi[illegible] Record* for March 2, 1912. Both bends had to be revetted on th[illegible] cave side to hold the river in check. Since 1882, when the brid[illegible] was started, over $1,425,000 have been spent in protection for thi[illegible] ture, an average of $44,530 per annum.

The presence of high banks is desirable, as they reduce the [illegible] the approaches and also better confine the floods to the main cha[illegible]

It is always best to cross the stream as nearly at right angles [illegible]

sible. Any departure from a right-angled crossing means a longer bridge and also skewed spans and longer piers, all of which features involve increased expense. In most cases, especially when the current is swift or the river is navigable, the piers should be set parallel to the direction of flow in the main channel, as they will then present less obstruction to the stream and to navigation, and as they will receive less pressure from the impinging water and will catch less drift.

If possible, the bridge should be so located, or the line should be so shifted, that the structure will be approached on tangents and not on curves. This will afford the trainmen the opportunity to see if the track is clear before reaching the structure, and will reduce the danger of derailment thereon to a minimum.

Another condition to be avoided is the location of a bridge at a sag in the grade, for such a sag would produce a change in direction of the moving mass as the train comes on, and would thus cause an increased load effect upon the structure. Also, it gives to the bridge an objectionable appearance.

The restrictions previously given and others established by the War Department (see Chapter L) will affect the economy of the structure.

In any event it will be necessary to determine the actual physical conditions by a preliminary survey. An alignment map and profile of the road for the crossing and for some distance on each side thereof should be obtained from the Railroad Company. If not obtainable, a preliminary survey should include the collection of that information. From such a map and profile it can readily be seen whether any modification in grade or alignment could advantageously be made.

If such modifications in the road can be effected, a stadia survey of the stream meanders should be made, tying it in with the former bridge location and covering such a stretch of the river as a reconnaissance shows to be desirable. This information when plotted in conjunction with the previous alignment will show whether a better bridge site is obtainable than the one first contemplated. In making a selection of a site, due regard must be paid to the cost of modifying the alignment of track as well as to the previously enumerated conditions for best bridge location. A selection having been made, the profile of the crossing can be run and soundings taken above and below it so as to show the topography of the stream-bed. At each end thereof the profile of the crossing should extend well back from the stream so as to include the entire space between extreme flood lines. With these data and with borings showing the material of the river bed and of the strata below, a tentative layout of structure may be made and the sufficiency of waterway tested, as per the directions given in Chapter XLIX. This preliminary survey should also include elevations and positions of high-water marks along the reach of the river considered; it should develop evidence of scour, if any; and it should determine the nature of the material composing the stream-

banks and flood plain, the character of the vegetation, the kinds and quality of the timber, the proportion of cleared or cultivated land, and the location of buildings and fence lines.

To decide upon the very best of several possible bridge locations, it is often necessary to make a number of complete estimates of cost not only of the bridge itself and its approaches, but also of the road for quite a distance from each end of the structure and extending to points that are common to all the layouts under comparison. Generally speaking, the least expensive of these is the one to adopt; but sometimes there are differences in the profile elevations which are of sufficient importance to influence the final choice of location by bringing into consideration the cost of operation and maintenance. A good bridge engineer will never permit himself to economize on time, labor, or expense when endeavoring to determine the economics of such an important problem as the best possible location for a costly structure.

[illegible]

[illegible] to fortify his judgment,
[illegible] wells and test-pits made in the
[illegible] any authentic published reports
[illegible] geological formations in that
[illegible] those published by the Gov-
[illegible] the large public libraries. The
[illegible] if he be not forewarned
[illegible] in any of the streams in
[illegible] the Ohio River and to the east
[illegible] in a river bed of this dis-
[illegible] gravel, clay, and boulders
[illegible] past ages the water in its per-
[illegible] lime to cause a cementing
[illegible] thus consolidated presents
[illegible] Also the striking of a large
[illegible] one is apt to draw the
[illegible] been encountered. Hence the

[illegible]

[illegible] borings have been developed,
[illegible] conditions. The simplest
[illegible] piece of pipe, to which other
[illegible] is rotated by hand and
[illegible] bringing up a sample of the
[illegible] with their depths and
[illegible] material, must be the basis
[illegible] is specially suitable for clayey

[illegible]

[illegible] borings." In this the ma-
[illegible] inside of a pipe, and floated

to the surface by means of a strong jet of water issuing from the drill point while it is at the bottom of the hole. This flow of water is supplied by a force pump and is transmitted to the drill point through the small pipe to which the said drill point is attached. From these washings, their depths, and the "feel of the drill," the engineer must form an opinion as to the kind of material passed through and its bearing capacity so as to decide upon where to rest the piers. This method is available for silt, sand, clay soils, shale, and, to a limited extent, rock.

Another method of underground exploration is that of "core drilling." In this the drill is constructed so that its rotation cuts out a cylindrical core extending upward inside the drill point and into the space within the churning pipe. This core is broken off at various times and brought to the surface, then it is taken out of the pipe and kept for future inspection and testing. This method permits of the engineer's seeing the various materials as they actually occur and in large enough pieces to judge of their characteristics and to make tests upon them, if so desired. It gives positive results and is best suited for the harder shales, sandstones, limestones, and granite formations. The overlying softer materials are usually penetrated by the wash boring process before the core drill is started.

After a hard stratum is discovered, it is desirable to penetrate it several feet so as to make sure that it has the requisite thickness for distributing the load from the pier, and that it is not merely a boulder. In limestone and sandstone formations there is always the possibility of striking subterranean caverns or overhanging cliffs due to former erosions in the earlier geological periods. To develop the presence or the absence of such underground caverns or cliffs, the drill should be shifted several feet sideways and another hole put down. A single boring at a pier site is not altogether conclusive. The author has often put down four holes for a single pier, one at each corner, but generally one hole per pier will suffice—or less for a wide crossing, if the conditions of the river bed be very uniform in respect to character of materials.

The equipment needed for making wash-borings consists of a two and a half inch pipe for casing and a one inch pipe for drill rod, both cut into eight-foot lengths for convenience in handling; several different kinds of drill points; a three-legged derrick or tripod with a pulley attached at the top for passing the rope that operates the drill; and a pump with a small hose to connect with the drill rod so as to supply the water needed for bringing the washings to the top of the casing. At the lower end of the rod a drill point is attached. The best drill point for all-around work has two cutting edges arranged in the shape of a cross. These crossed edges of the bit break any pebbles that come into the hole and do not allow them to ascend with the water and to jam the drill pipe against the casing. This drill point has holes in the sides from which the water flows, as, in fact, do most of the other types of drill points em-

[illegible] for

[illegible] with [illegible] clamp-

[illegible] attached.

[illegible] Catalogue, Fig. 404, page

F. M. & Co. Catalogue No. 60,
[illegible] for each cutter.

[illegible] & Co. Catalogue No. 60, Fig.
[illegible]ading 1 in. and 2½ in. pipe.
[illegible] dies, page 505–506, F. M. & Co.

[illegible] Co. Catalogue No. 50, Fig. 775,

F. M. & Co. Catalogue No. 50,

Catalogue No. 50, Fig. 103, page

[illegible] tongs No. 3, F. M. & Co. Catalogue No. 60, Fig.

[illegible] puller and dies, No. 2 with 2½ in. dies, F. M. & Co. C
[illegible] Fig. 115, page 531.

[illegible] Jack screws, 14 in., ten ton capacity, F. M. & Co. Catalogue
[illegible] page 462.

12 ft., ⅜ in. chain to use in pulling pipe with levers.

2 Single blocks, 4¾ in. sheaves, F. M. & Co. Catalogue No. 60,
[illegible] page 533.

1 Single block, 4¾ in. sheave, F. M. & Co. Catalogue No. 60, Fig.
page 533.

1 Double block, 4¾ in. sheave, F. M. & Co. Catalogue No. 60,
[illegible] page 533.

100 ft., ¾ in. manila rope.

1 Hand hammer No. 1.

1 Sledge hammer No. 12.

1 Hand saw (cross-cut).

1 Monkey wrench.

1 Pocket alligator wrench, F. M. & Co. Catalogue No. 60, Fig.
page 515.

1 Brace and ¾ in. bit.

1 Hand axe.

1 Chopping axe.

1 Screw driver, 6 in.

1 Triangular file, 12 in., F. M. & Co. Catalogue No. 60, Fig.
page 520.

1 Mill bastard file, 12 in., F. M. & Co. Catalogue No. 60, Fig.
page 520.

2 Steel hand chisels.

1 Caulking iron for caulking barges.

1 Oil can and oil.

3 2½ in. drill bits, F. M. & Co. Catalogue No. 60, Fig. 615, page

1 2 in. expansion bit, F. M. & Co. Catalogue No. 60, Fig. 610,
354.

1 Taper tap for 1 in. pipe, F. M. & Co. Catalogue No. 60, Fig.
page 354.

4 Drive heads for 2½ in. pipe, F. M. & Co. Catalogue No. 60,
94, page 352.

2 Forged steel shoes for 2½ in. pipe, F. M. & Co. Catalogue No.
Fig. 421, page 353.

3 Drive rings. These will have to be manufactured specially
machine shop.

½ dozen 1 in. elbows.

1 2½ in. tee.

½ dozen hydraulic recessed couplings.

[illegible]

it is not always nec-
to pull the entire casing pipe and
a half inch pipe is sufficiently
a drive-tube one may be used
portion of the casing is exposed
a larger pipe will be better than
leakage the pump should be
of water is needed to bring
cases it will pay to use a gaso-
horse-power.

stream where the current is too
will be best to use two small scows
can be placed alongside and
so as to leave an opening for the
to prevent the swaying and tilt-
the pipe. Timbers are laid
to the boats so that they will act
able for equalizing the pressure
over the centre of the space
frame, from which the drill is
it will be necessary to tie to some
of anchors upstream. These
boxes with rock or concrete and
the water. For river work it will
connect the boats to the anchors. A
should be fastened to each anchor
it to float on the surface. It will
snagged and have to be tripped.
pieces of timber, each 2″×6″×20′
platforms should be constructed,
second six and a half feet above
of the casing.

encountered, it becomes a diffi-
breaking the couplings. A case
for a bridge across the At-

[illegible] was driven [illegible]
[illegible] below the bed of the river
[illegible] or four feet above the water surface, a
[illegible] thereon. Two barrels were employed to hold
[illegible] which was pumped through the drill-pipe instead
[illegible] As this puddle overflowed from the top of the
[illegible] was returned to the barrels and used over again.
[illegible] hold together, so that a depth of over 120 feet
[illegible] process in less than five hours.

[illegible] the casing become gripped in the material penetrated
[illegible] prove futile, a portion of it can be saved by
[illegible] dynamite to a coupling about 20 feet below the bed of the
[illegible] thereof will break the coupling so that the upper
[illegible] can then be pulled and used over again. Should
[illegible] near the bed of the river, it is best to move the
[illegible] away and start a new hole; however, should there
[illegible] bed of boulders, it may be necessary to break up the
[illegible] with a charge of dynamite. Before placing the
casing should be withdrawn three or four feet in order to avoid its
injured. After the boulder is shattered, the casing pipe can be
provided the expansion bit is used to enlarge the hole.

The equipment needed for the core-drilling process is similar in
respects to that for wash borings. An outside casing is used,
casing is driven to bed-rock and washed clean inside by means of a
jet before the core-drill is started. The core-drill bit is a ring,
in one type with black diamonds for the cutting agent, and in
type with chilled steel shot. The bit in either case is rotated by
of the hollow rods to which it is attached and through which a
of water is kept flowing, except when going through clay or soft
A core barrel some ten feet long is provided above the bit.
steel-shot type no attempt is made to wash the cuttings to the
cause the required flow of water is so great as to disturb the shot.
cuttings are carried into the core chamber and brought to the
when the core is lifted. With the diamond bit a strong stream of
is employed so that the cuttings are lifted to the top, otherwise
would wedge about the drill and finally stop it. This stream serves
to keep the bit cool.

Dry cores in clay and the softer shales can be made with a saw
bit. They are desirable because they give a more exact
the resistance of the material. Unless dry cores are taken, a
or a shale suitable for a foundation might be overlooked. Power
quired to rotate the core-drill. The most usual difficulty
with core-drilling operations is the sticking of the bit in the hole.
is apt to happen in soft and caving rock, and it is sometimes

[illegible] ready for withdrawal
[illegible] with a strong jet of water
[illegible] the bit from jamming. No
[illegible] would interfere with the
[illegible] it is necessary to wash in
[illegible] barrel. This is tedious and
[illegible] when pulling up the drill,
[illegible] or even ground to pieces.
[illegible] from these various methods
[illegible] into consideration when inter-
[illegible] to be served by the said borings.
[illegible] boring method will usually be
[illegible] prevalent. If the character of
[illegible] resistance are desired, the core-
[illegible] tendency of wash borings is to
[illegible] encountered, especially with a
[illegible] is dissolved and carried off.
[illegible] as sand, and sand to appear as

[illegible] so much with different localities
[illegible] presenting all the data that enter
[illegible] desires to obtain detailed informa-
[illegible] well to consult the standard hand-
[illegible] method is the most expensive,
[illegible] the auger method is the cheapest.
[illegible] in a great many cases is such

[illegible] of method is by no means the guiding princip [illegible] there are many cases in which there is no possible ch [illegible] owing to existing conditions which render only one appli [illegible] a conclusion to this chapter, in the hope that the inform [illegible] will prove useful to some of his readers, the author repro [illegible] follows the blue-printed instructions that his firm furnishes to [illegible] boring parties:

"Pipe may be purchased close to where the borings are to be ma thus saving freight charges. In cases where the borings are to go to depth of more than 50 or 60 ft., it is best to get the extra heavy pipe fo both two and one-half inch and one inch sizes; but in shallow boring the ordinary thicknesses for two and one-half and one inch pipes wi answer.

"For ordinary conditions the pipe is purchased in Kansas City, and about 200 ft. of 2½ in. and 120 ft. of 1 in. pipes should be shipped. Thi may do the boring for one river crossing, providing it can be pulled afte each boring is finished, and so used repeatedly. The casing pipe ca nearly always be pulled out when making borings on land, but where there is a great penetration it is a difficult matter to pull pipe from scows. In such cases a small charge of dynamite lowered on the inside so as to break off the pipe at or below the bottom of the river will be the easiest and cheapest way to get rid of it. The pipe above the ground line can be saved, and possibly some more.

"It is advisable and will save a great deal of hard labor to have th pipe, both 2½ in. and 1 in., cut in lengths of about 8 ft.; but two lengt of 16 or 18 ft. of the 2½ in. pipe can be shipped without being cut. A pieces of pipe are to be threaded on both ends. The threads must deep enough so that the ends of the pipe will come in contact in a coupli This applies both to the 1 in. and the 2½ in. pipes. A coupling (long hydraulic) should be put on one end of each pipe, and a dozen cou lings for 2½ in. pipe and another dozen for 1 in. pipe should be ship extra.

"Drive caps, Fig. 94 of Fairbanks, Morse & Co.'s Catalogue, can used only for light driving. As furnished, they are not complete our method of work; and a hole 1 7/16 in. in diameter must be drilled ver tically through the cap. For deep borings the steel drive heads, su as shown in Fig. 48*a*, are required; and they have to be made special in a machine shop.

"Care should be taken to see that the drills fit the casing pipe, as may be hard to get them ground down in the field if too large; and too small they will not work well.

"Use the hydraulic recessed couplings for fastening the drive he to the casing pipe and to the ram, and be sure the coupling is scre onto the drive head and onto the pipe as far as possible. This will red the danger of stripping the threads while driving.

Driving Casing Pipe.

borings may sometimes suffice. as to how many borings will

pipe, is driven by a ram con- feet long, lifted and dropped by casing pipe is fitted with a drive ram. The 1″ pipe, called the wash during the process of driving down and serves as a guide for the ram.

during the driving of the casing, a near the centre can be used in for the ram. The length of this be less than 4½ feet.

removing the drive head is shown been removed, connection is made shown in Fig. 48*d*, and the material to the directions there given. 6 or 8 feet at a time without Fig. 48*e*, at the connection of the to pass through it continuously . This is absolutely necessary

when drilling in rock, as it is essential to keep continually turning the pipe in order that the drill may cut a uniformly round hole and thus eliminate the danger of its getting stuck. In soft material the wash pipe will sink of its own weight as it washes out the earth in the casing pipe, but in hard material it is necessary to raise and drop it, using it as a drill. In such cases the lower end of the wash pipe terminates in a cutter, having orifices through which the water passes. For this drilling it is necessary to have a sheave and a line passing to the wash pipe to lift and drop it, as shown in Fig. 48*d*.

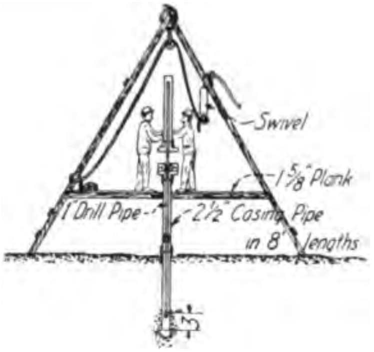


FIG. 48*b*. Driving Casing for Borings.

NOTE.—The drill point should always be at least 3' 0" above the bottom of casing when driving, so that sand and gravel will not be forced up inside of casing and bind the drill.

Coupling of 1" drill pipe resting on lower drive-head supports drill pipe while driving casing, the two rings forming a protection for coupling as shown.

Drive-heads must be screwed into coupling for full length of thread.

The piece of 1" pipe above coupling serves as a guide for the ram.

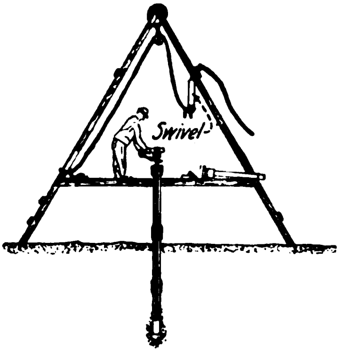


FIG. 48*c*. Removing or Replacing Drive-head.

NOTE.—To remove or replace drive-head, raise up drill pipe so as to bring the drill well up above the bottom of casing, and hold drill pipe with wrench or line until the coupling is removed and drive-head dropped over top of 1" pipe. The coupling is then to be screwed on top of 1" pipe and allowed to drop down on drive-head to support the drill pipe during driving. Reverse operation to remove the drive-head.

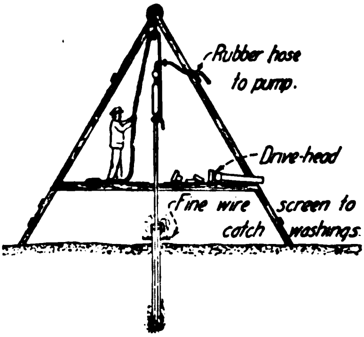


FIG. 48*d*. Drilling when Making Borings.

NOTE.—To operate drill, raise up and let fall, at the same time keeping a good flow of water passing through pipe.

"The material washed out of the casing pipe must be caught so that its nature can be determined. A record must be kept of the different

[illegible] or gravel is
[illegible] the casing must be driven
[illegible] sand nor the gravel will stand
[illegible] through without the casing. In
[illegible] can be made if the drill pipe
[illegible] drilling in rock.
[illegible] to the surface that the casing
[illegible] drill pipe must be withdrawn, the
[illegible], and the casing re-driven. It is
[illegible] the surface than to try to work
[illegible]ntered at a great depth, it will be
[illegible] method is to rig up the apparatus
[illegible] the case must be washed out to the
[illegible], say ¼ lb., must be weighted and
[illegible] pipe must be pulled 4 or 5 ft. above
[illegible] Waterproof fuse or electric battery
[illegible]. If the casing pipe is too deep to be
[illegible] drill must be used to pierce the
[illegible] it must be done.

[illegible], the expansion drill should be used
[illegible] the casing pipe must be driven into
[illegible] flow of sand and make the remain-
[illegible] bit should be removed and the
[illegible]-rock. If it proves to be hard, from
[illegible] to penetrate; but should it be shale
[illegible] drilled into from 10 to 12 feet.

"It will be necessary to work six men on borings. These can generally be picked up in the vicinity of the work.

"The scaffolding shown in Figs. 48*b*, 48*c*, and 48*d* has only one working platform. It is much more convenient and much easier on the men to have at least two working platforms, and the work can be done much more quickly. The sketch illustrating the barges in position with scaffold erected (Fig. 48*f*) shows a better arrangement, as it gives plenty of working room both for handling the pipes and for driving the casing.

"For work in the river it is preferable to have two small scows to work on, providing they can be rented. If they are not obtainable, one medium-sized scow will suffice. In case the two small scows are available, they can be fastened together, and a tower with suitable working platforms erected thereon, as shown by Fig. 48*f*.

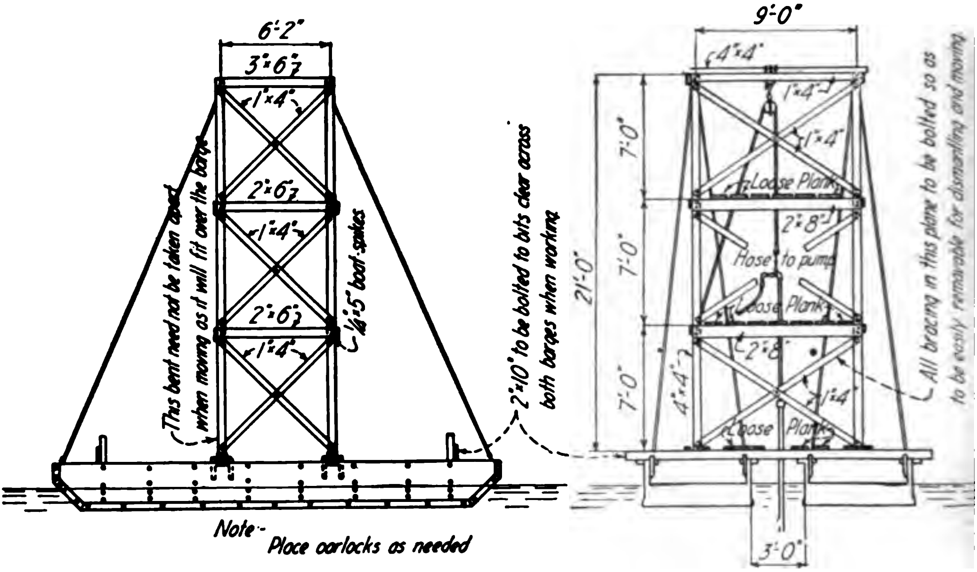


FIG. 48*f*. Equipment for Making Borings from Barges.

"In case the two scows are not available, the work can be done from one scow. This can be accomplished with a tower of the same dimensions resting on two timbers extending over one end. They must be bolted or secured rigidly to the scow so that there shall be no danger of their tipping up. A little less than one-half of the tower can be on the scow.

"In case no scows are available, it will be necessary to build a couple of small ones. Fig. 48*g* shows a very satisfactory design. To hold the scows it will be necessary to anchor them from each corner. Boxes filled with stone will suffice for anchorage, but the regular iron anchor will be much better, especially on a stream with swift current. The anchor lines to each anchor must be at least 150 ft. long in order to get good

Making Boring.

red light must be placed in the
so located as to be seen from all

and from the barges. It will be
a skiff, paying him about 50 cents
the same wages as the other men
$2.00 per day. In case a man
be bought, rented, or built.
at some distance away from water,
point through the sand until water
pumping. If it happens to be so deep
, a couple of barrels must be se-
water thereto from the river. When
employed continuously by collecting
be done by procuring a T con-
pipe, placing a short piece of
another short piece into it hori-
be attached and the end placed
it flows from the casing pipe.
any pipe with the tools, unless
pipe on hand could be shipped and

used more cheaply than to buy new pipe. Sell the pipe if possible; if unable to do so, discard it.

"Under special conditions it may be more economical to use a gasoline engine to run the pump and to lift the drill pipe when drilling instead of employing man power. A two-horse-power engine will furnish ample power to do this. The engine, No. 140, shown in Fairbanks-Morse & Company Catalogue No. 60, page 255, is suitable for this purpose. The walking beam shown is not required, but the pump can be connected directly to the pitman rod there indicated. The minimum stroke with this engine (5″) at the given speed (47 r.p.m. of pump gear) will give too much water, so that it will be necessary to shorten the stroke by connecting the pitman rod to the upright piece of the pump handle a sufficient distance above the piston of the pump to give the required length of stroke. Probably a 2″ stroke will be sufficient. For lifting the drill pipe it will be necessary to rig up a spool on a shaft independent of the engine, with a pulley for a belt connection to the pulley on the engine. By taking a couple of turns around this spool with the line from the drill pipe, the latter is easily raised by a slight pull on the line leading from the spool and dropped by slacking on the same. The above outfit requires three men to operate. It can be used economically where labor is scarce and wages are high. Another advantage under such conditions is that the work is much easier and, therefore, there is not the danger of continually losing the men about the time they get accustomed to the work. Where the material in which the boring is being made is such that the drill pipe can be carried down without the casing pipe the advantage of the engine is much increased, and, conversely, where the casing pipe has to be driven down all the way the use of the engine loses much of its advantage. This is because with hand operation the entire six men can be utilized when driving, while three men will not make very good progress where there is much driving to do. It is possible to raise the ram with the engine, but driving with the engine raising the ram is not nearly so effective. Fig. 48*h* shows the arrangement of the gasoline engine, pump, etc.

"Before the work is started, employers' liability insurance is to be taken out on all men employed upon or connected with the work. This can usually be obtained in the town nearest to the site of the borings by application to some insurance agent. We want to be thoroughly protected in the work; and, therefore, proper insurance must be taken out.

"Usually we are given by the company stakes on the bridge tangent; and then borings will be located by their station number. Where we establish the bridge tangent the station numbering is ordinarily fixed by some natural object, say the centre line of some cross street, a railroad track, etc. For ordinary cases, or where the water is not more than 500 feet across, the position of each boring can be determined by measuring out with a tape, or with a wire and then measuring the wire. For wider

streams it will be necessary to lay out a rough triangulation system and measure the angle between base line and boring. Extreme accuracy is not essential, as a variation of a couple of feet is no serious matter. The angle can be read when convenient and the plus of the boring figured.

"Usually we are given a bench mark, or else some permanent bench mark referred to some assumed base is selected. It is well to place a gauge so that the elevation of the water can be noted at least once a day. Elevations of pipe are generally determined from the water and so referred to datum. It is well to establish levels at once and refer all measurements to proper datum.

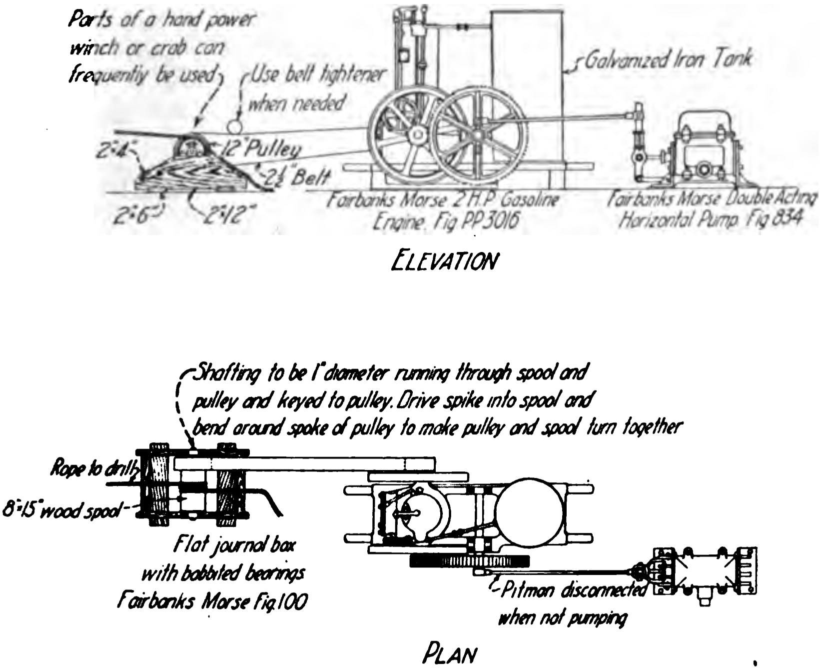


FIG. 48*h*. Arrangement of Gasoline Engine for Making Borings.

"As soon as the engineer reaches the site he should write a letter to the Main Office, giving full particulars as to how the conditions appear to him. Every day thereafter a daily report is to be sent on the blanks supplied. (See Fig. 48*i*.) One report is to be mailed each night giving the information for that day. Special notes may be made on the reports so that no other letters are necessary.

"When the work is concluded, a final letter should be written, advising as to the disposal of tools, equipment, old pipe, etc., and sending bills of lading for shipments.

"Take receipts for all expenditures for materials and wages, rents, etc., on the blanks furnished."

FIG. 48i

REPORT SHEET FOR BORINGS

Waddell & Harrington
Consulting Engineers
Kansas City, Mo.

Daily Progress Report on Borings

No...........

Name of River........................... Made for..................................

Day...................... Date...................... Weather..................

Boring No............. Station No...............

Elevation of water..

Elevation of ground line.....................................

Elevation of bottom casing pipe yesterday, 6:00 P.M...........

Elevation of bottom casing pipe to-day, 6:00 P.M...............

Elevation of bottom of hole yesterday, 6:00 P.M................

Elevation of bottom of hole to-day, 6:00 P.M..................

Material passed through.....................................

....

Work done today ....

....

....

....

....

Materials purchased..

....

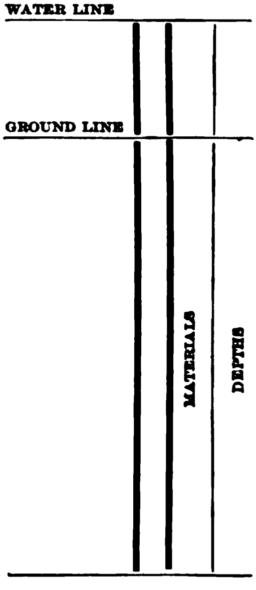
....

General notes..

....

....

....



FINAL SKETCH

EMPLOYED ON WORK

NAME	CAPACITY	HOURS	RATE		TOTAL COST	

ENGINEER IN CHARGE

CHAPTER XLIX

DETERMINATION OF WATERWAYS

After the location of a bridge has been chosen, it often becomes necessary to determine how much waterway should be allowed before further progress can be made in deciding on an economical and safe layout. The importance of this question varies with the size and cost of the bridge. On new work it is often desirable to put in temporary wooden trestles, in order to afford an opportunity for accurate observations and intelligent study of each problem. This is especially true in new countries where drainage areas have not been accurately mapped and where reliable information concerning rainfall and high-water elevations is unobtainable.

The following data are useful in determining areas of waterways; and as many of them as can be secured at reasonable cost should always be collected as soon as practicable.

1. Cross-section of stream and valley.
2. Elevations of extreme high water and ordinary high water.
3. Alignment of stream for a distance above and below the bridge equaling in length several times that of the proposed structure.
4. Area of existing waterway.
5. Character of adjacent lands. ✓
6. Maximum discharge in extreme floods. ✓
7. Profile of flood line.
8. Measurements or estimates of velocity.
9. Sizes of openings of other bridges on the stream located near to, below, and for some distance above the proposed site, and information as to whether these structures have proved adequate.
10. Map of drainage area above proposed bridge (U. S. topographic maps, if these can be had, are preferable).
11. General slopes.
12. Magnitude of floods and frequency of their occurrence.

In many cases it is not necessary to spend much time on the study of the required area for waterway; because local features, War Department regulations, pecuniary restrictions, and other conditions than hydraulic ones will settle the layout; but in such cases after the tentative arrangement of spans, piers, pedestals, abutments, and approaches has been prepared, a rough check on the hydraulics involved should be made so as to ensure that the structure will never be likely to cause trouble of any kind on account of insufficient allowance for waterway.

As a rule, calculations for waterway areas are restricted to small

[illegible] been proposed and adopted [illegible] many of these are widely divergent [illegible] governing conditions, such as area of [illegible] rainfall, intensity, extent, and duration of [illegible] and its tributaries, character of soil, and [illegible] vegetation. These factors certainly constitute a [illegible] divergence in the resulting values of [illegible] calculated by the various formulæ that have [illegible] by the engineering profession; but they [illegible] reason for the ridiculously large variations [illegible] applying such formulæ to some particular case. [illegible] in mind that, at the best, the solution of this problem [illegible] and that familiarity with the physical conditions [illegible] inspection on the ground is advisable before [illegible] hereinbefore mentioned as desirable for its determination.

The first step to take is to decide on what magnitude of flood [illegible] provided for. Extreme floods may occur but once or twice in [illegible] and the cost of caring adequately for such a contingency is [illegible] unwarranted in many instances. Here the best judgment of the [illegible] will be needed; for the temptation will be to use too rigidly the [illegible] that the loss due to the extreme flood is justified if it does not [illegible] capitalised cost of the additional waterway necessary to prevent [illegible] difficulty in applying this principle is to foresee all the items [illegible] enter into some future loss, and thus arrive at a true aggregate [illegible] engineer should be liberal in assuming the magnitude of the [illegible] to be provided for as well as in forecasting the probable amount of [illegible] that in the future might be caused by an abnormally great flood.

In Vol. 12, Part III, of the *Proceedings* of the American [illegible] Engineering Association will be found a collection and résumé [illegible] principal formulæ for sectional areas and discharges of streams, [illegible] by a special committee. Their preliminary or tentative [illegible] submitted to the Association in March, 1909, were prefaced by the [illegible] ing remarks:

"(1). In determining the size of a given waterway, careful [illegible] tion should be given to local conditions, including flood height [illegible] size and behavior of other openings in the vicinity carrying the [illegible] stream, characteristics of the channel and of the watershed area, [illegible] conditions, extent and character of traffic on the given line of [illegible] probable consequences of interruptions to same, and any other [illegible] likely to affect the safety or economy of the culvert or opening.

"(2). (*a*). The practice of using a formula to assist in [illegible] proper size of the waterway in a given case is warranted to the [illegible] the formula and the values of the terms substituted therein are [illegible] to fit local conditions.

"(*b*). Waterway formulas are also useful as a guide in fixing or verifying culvert areas where only general information as to the local conditions is at hand.

"(*c*). The use of such formulas should not displace careful field observation and the exercise of intelligent judgment on the part of the engineer.

"(*d*). No single waterway formula can be recommended as fitting all conditions of practice."

The object of the standing "Sub-Committee on Formula for Waterways," appointed and continued by the Association, is apparently to find a single formula that "can be recommended as fitting all conditions of practice," and although the members of that committee evidently are somewhat discouraged by the complexity of the problem and the widely differing formulæ proposed, they have not yet given up all hope of success. In their 1911 report they conclude thus:

"(1). There is a general relationship between the best-known waterway and run-off formulas. This relationship may be expressed by two terms, a varying coefficient and a varying exponent. . . .

"(2). The extent of this relationship for large and small areas is indicated by the Dun waterway data. . . ."

In Table 49*a* are given the said data, compiled by the late James Dun, an American engineer whose important work and sterling worth entitle his memory to a broader recognition than his professional reputation has yet received. It was the author's good fortune to become acquainted with him over a quarter of a century ago in connection with the bridging of the Colorado River at Red Rock on the line of the Atlantic and Pacific Railway. That business association and occasional meetings in later years served to impress upon the author the value of Mr. Dun's services to the engineering profession, especially in connection with his work for the Santa Fé Railway System.

Column 2 in Table 49*a* is prepared from observations of streams in Southwest Missouri, Eastern Kansas, Western Arkansas, and the southeastern portions of the Indian Territory. In all this region, steep, rocky slopes prevail, and the soil absorbs but a small percentage of the rainfalls. It indicates larger waterways than are required in Western Kansas and level portions of Missouri, Colorado, New Mexico, and Western Texas.

The classification by States is for convenience only, and merely denotes the general characteristics of topography and rainfall.

A study of the various formulæ for area and discharge at any crossing, given in Appendix A of the before-mentioned sub-committee's report on page 490 *et seq.* of the 1911 *Proceedings* of the A.R.E.A., shows why such great discrepancies exist in computed values. The general form of the various formulæ for sectional area is

$$A = CM^n, \qquad \text{[Eq. 1]}$$

TABLE 49a

THE DUN DRAINAGE TABLE

Atchison, Topeka & Santa Fé Railway System (1906)

Areas Drained in Square Miles	Areas of Waterway						
	Missouri and Kansas	Cast Pipe For Banks Over 15 Feet Use 80%	Box and Arch Culverts 1st Fig.—Diam. 2nd Fig.—Bench	Percentage of Column 2			
				Illinois	Indian Territory	Texas	New Mexico
1	2	3	4	5	6	7	8
.01	2.0	1-24"	2 × 1B	West of Streator, use 80 per cent.—East of Streator, use 60 per cent.	North of Purcell, use Column 2.—South of Purcell, use Texas Column.	Use Column 2.	Use Column 2.
.02	4.0	1-24"	2 × 2B				
.03	6.0	1-30"	2 × 3B				
.04	7.5	1-36"	2½ × 3B				
.05	9.0	1-42"	3 × 3B				
.06	10.5	1-42"	3½ × 3B				
.07	12.0	1-48"	3 × 4B				
.08	13.5	2-36"	D 2½ × 3B				
.09	15	2-36"	D 2½ × 3B				
.10	16	2-36"	D 3 × 3B				
.15	25	2-48"	D 3 × 4B				
.20	32	3-42"	6 × 4A				
.25	38	3-48"	6 × 5A				
.30	44	.....	6 × 5½				
.35	51	.....	8 × 4½				
.40	56	.....	8 × 5A				
.45	62	.....	8 × 6A				
.50	66	.....	8 × 6A				
.55	70	.....	8 × 6½				
.60	74	.....	10 × 4½				
.65	78	.....	10 × 5A				
.70	81	.....	10 × 5½				
.75	85	.....	10 × 6A				
.80	88	.....	10 × 6½				
.85	91	.....	10 × 6½				
.90	94	.....	10 × 6½				
.95	97	.....	12 × 5A				
1.0	100	.....	12 × 5A				98½
1.1	110	.....	12 × 6A			105	98½
1.2	120	.....	12 × 7A			105	98½
1.3	130	.....	12 × 8A			105	98½
1.4	140	.....	14 × 6½			105	98½
1.5	150	.....	14 × 7A			105	98½
1.6	160	.....	16 × 6½			105	98½
1.7	170	.....	16 × 7A			105	98½
1.8	180	.....	16 × 7½			105	98½
1.9	190	.....	16 × 8A			105	98½
2.0	200	.....	18 × 7A			105	98½
2.2	220	.....	18 × 8A			105	98½
2.4	240	.....	18 × 9½			105	98½
2.6	260	.....	20 × 8A			105	98½
2.8	280	.....	20 × 9A			105	98½
3.0	300	.....	20 × 9½			105	98½
3.2	321	.....	22 × 8½			105	98½
3.4	340	.....	22 × 9A			105	98½
3.6	357	.....	24 × 8½			105	98½
3.8	378	.....	24 × 9A			105	98½
4.0	388	.....	28 × 7A			105	97
4.2	403	.....	28 × 7½			105	97
4.4	417	.....	28 × 8A			105	97
4.6	430	.....	28 × 8½			105	97
4.8	443	.....	28 × 9A			105	97
5.0	455	.....	28 × 9½			105	97
5.5	483	.....	28 × 10A			105	97
6.0	509	.....	32 × 7½			105	97
6.5	533	.....	32 × 8A			105	97
7.0	556	.....	32 × 9A			105	97
7.5	579	.....	32 × 10A			105	97
8.0	601	.....	32 × 11A			105	97
8.5	622	.....	32 × 11½			105	97
9.0	641	.....	32 × 12A			105	93½
9.5	660	.....	32 × 12½			105	93½
10	679	.....	32 × 13A			105	93½
11	710	.....	Bridges designed to provide area according to circumstances.			105	93½
12	740	.....				105	93½
13	775	.....				105	93½
14	805	.....				105	93½
15	835	.....				105	93½
16	865	.....				105	94
17	890	.....				105	94
18	920	.....				105	94
19	945	.....				105	94
20	970	.....				105	94
22	1,015	.....				105	94
24	1,060			West of Streator, use 80 per cent.—East of Streator, use 60 per cent.	North of Purcell, use Column 2.—South of Purcell, use Texas Column.	110	94
26	1,100					110	92
28	1,140					110	92
30	1,180					110	92
32	1,220					110	92
34	1,255					110	92
36	1,290					110	91
38	1,320					110	91
40	1,350					110	91
45	1,435					110	91
50	1,510					110	89½
55	1,580					115	89½
60	1,650					115	89½
65	1,720					115	88
70	1,780					115	88
75	1,840					115	88
80	1,900					115	86½
85	1,960					115	86½
90	2,015					115	86½
95	2,065					115	86½
100	2,120					120	85
110	2,220					120	85
120	2,315					120	85
130	2,405					125	83½
140	2,500					125	83½
150	2,580					130	82
160	2,665					130	82
170	2,745					130	80½
180	2,820					130	80½
190	2,900					130	79
200	2,970					130	79
220	3,115					130	77½
240	3,245					130	77½
260	3,370					130	76
280	3,495					130	76
300	3,615					130	74½
325	3,770					130	74½
350	3,900					130	73
375	4,035					130	73
400	4,165					130	71½
450	4,385					130	70
500	4,610					130	68½
550	4,825					130	67
600	5,030					130	65½
650	5,230					130	64
700	5,420					130	62½
750	5,610					130	61
800	5,800					130	59½
850	5,890					130	58
900	6,080					130	56½
950	6,230					130	....
1,000	6,380					130	....
1,100	6,705					130	....
1,200	6,960					130	....
1,300	7,230					130	....
1,400	7,480					130	....
1,500	7,725					130	....
1,600	7,960					130	....
1,700	8,195					130	....
1,800	8.390					130	....
1,900	8 625					130	....
2,000	8 820					130	....
2,200	9,240					130	....
2,400	9,605					130	....
2,600	9,970					130	....
2,800	10,320					130	....
3,000	10,640					130	....
3,500	11,445					130	....
4,000	12.160					130	....
4,500	12,825					130	....
5,000	13,500					130	....
5,500	14,080					130	....
6,000	14,520					130	....
6,500	15,140					130	....

D = Double. Culvert. A = Arch Culvert.

where A is the sectional area of stream in square feet, C is a factor that has different values according to the character of the country drained, M is the area drained in acres, and n an exponent varying from 0.5 to 1.0. The very fact of the wide range of this exponent shows that it is impracticable for the values of A to agree at all closely, no matter how much the value of C may be juggled with. For instance, taking Myers' formula, which is

$$A = CM^{\frac{1}{2}} \qquad \text{[Eq. 2]}$$

and Peck's formula, which is

$$A = \frac{M}{C}, \qquad \text{[Eq. 3]}$$

and assuming M to be 160,000 acres, Myers' formula will give

$$A = 400\,C$$

and Peck's will give

$$A = \frac{160{,}000}{C}.$$

In the former C varies from 1 to 4 and in the latter from 4 to 6. Taking the larger value in each case so as to obtain the closest possible agreement, we have by the Myers' formula

$$A = 1{,}600$$

and by Peck's

$$A = 26{,}666.$$

It is simply impossible to harmonize two such conflicting formulæ. In all probability both are incorrect and the truth lies somewhere between them. Dun's table gives by interpolation for an area of 160,000 acres (250 square miles) in Missouri and Kansas

$$A = 3{,}308,$$

and for Texas

$$A = 4{,}300.$$

Talbot's formula is

$$A = CM^{\frac{3}{4}}, \qquad \text{[Eq. 4]}$$

C varying from $\frac{1}{3}$ to $\frac{1}{6}$ or even less.

Wentworth's formula is

$$A = M^{\frac{2}{3}}. \qquad \text{[Eq. 5]}$$

The Tidewater Railway formula is

$$A = 0.62\,M^{\frac{7}{10}}. \qquad \text{[Eq. 6]}$$

These last three formulæ appear to be more reconcilable, although it is evident that as the exponent varies from 0.67 to 0.75, if, by change of

coefficients, they be made to agree for a small value of M, they will diverge considerably for a very large one. Applying the same value as before, viz. $M = 160{,}000$ acres, we find the following values of A:

By the Talbot formula	$8000\ C$
By the Wentworth formula	2947
By the Tidewater formula	$0.62 \times 4394 = 2724$

If C be made $\frac{1}{3}$ in the Talbot formula, which is applicable to areas three or four times as long as wide and subject to floods from melting snow, we shall have for this case

$$A = 2666.$$

These three formulæ check very well for an area of 250 square miles, which is not far from the superior limit of the Talbot formula, and possibly as large as any of the actual areas from the observations concerning which were derived the other two. It will be well, though, to test them all for much smaller areas, say 50 square miles or 32,000 acres. By substitution we find the following:

By the Talbot formula	$2393\ C$
By the Wentworth formula	1008
By the Tidewater formula	833
As before, making $C = \frac{1}{3}$ in the Talbot formula gives	798

From Dun's table we find the area to be 1,510 for Missouri and Kansas and 1,661 for Texas, or more than that given by any of the three formulæ and twice that obtained from Talbot's. The author's judgment in respect to choice of formulæ for sectional areas of streams would be to discard them all and use Dun's Table, which gives data based on actual records up to areas of 6,500 square miles.

There are many discharge formulæ given in the "Appendix" before mentioned, most of which are more or less complicated, and many of them containing terms that the engineer who has the problem to solve cannot obtain. For instance, the velocity of the stream during floods is often not on record, in which case he would have the choice of making a bald guess at its value, waiting (possibly for many years) for a big flood, or using some other formula. Evidently those formulæ which contain the fewest terms, other things being equal, would be the most serviceable; but, on the other hand, the fewer the terms the less, probably, the accuracy. The most promising looking of all the "volume" formulæ recorded are the following:

Fanning's, $Q = 200\, M^{\frac{5}{6}},$ [Eq. 7]

where Q = discharge in cubic feet per second,
and M = area of watershed in square miles.

Burkli-Ziegler's, $q = cr \sqrt[4]{\frac{s}{a}}$, [Eq. 8]

where q = discharge in cubic feet per second per acre,
c = coefficient,
r = average intensity of rainfall during heaviest downpour in cubic feet per second per acre,
s = general slope of watershed in feet per hundred,
and a = area of watershed in acres.

McMath's, $Q = cv \sqrt[5]{SA^4}$, [Eq. 9]

where Q = discharge in cubic feet per second,
c = proportion of rainfall reaching stream,
v = cubic feet of water falling upon an acre of surface per second during heaviest rain,
S = slope in feet per thousand,
and A = drainage area in acres.

Kuichling's, $q = \frac{44{,}000}{M + 170} + 20$, [Eq. 10]

where q = discharge in second feet per square mile,
and M = drainage area in square miles.

Murphy's, $q = \frac{46{,}790}{M + 320} + 15$, [Eq. 11]

where q = discharge in second feet per square mile,
and M = drainage area in square miles.

C. B. & Q. Ry., $Q = \frac{3{,}000\,M}{3 + 2\sqrt{M}}$, [Eq. 12]

where M = the area in square miles,
and Q = discharge in cubic feet per second.

In Vol. 12, Part III, page 505 *et seq.*, of the *Proceedings* of the American Railway Engineering Association there is given a table in which are recorded the results of some 450 studies of rainfall and its effects on streams. These records show the name of stream, place of study, drainage area in square miles above the latter, date of study, discharge in cubic feet per second per square mile (or, as it is commonly known, the "run-off"), period of record, duration of record, total discharge in cubic feet per second, waterway in square feet required as per Dun's Table, hypothetical velocity in feet per second at the place of study, and the authority for data recorded. The observations are divided into seven groups, covering the following portions of the United States.

1. Northeastern.
2. Middle Atlantic.
3. Southeastern.

4. Central.
5. Southwestern.
6. California.
7. North Pacific Slope.

In order to render this information readily available, the recorded on a map of the United States (Fig. [illegible]) all of the given on the table, and has plotted thereon in addition the curves for the entire area. He has also compiled from the each group, averages of the values of the records of drainage offs, hypothetical velocities, and average annual rainfalls, corded the same in the following table, numbered 49b, together eral averages of all these figures for the entire country, the said being computed in two ways, first, in the ordinary manner from sets of figures in the table, and, second, from the same by giving eration to the relative number of observations per group as with the total number of observations. The last two lines of are not of much practical value; but they serve to give one a of the average rainfall, run-off, and stream mean velocity for try as a whole. Curiously enough, these figures are 35, 3.5, which fact renders the task of remembering them quite easy.

TABLE 49b

RAINFALLS AND RUN-OFFS FOR VARIOUS PORTIONS OF THE UNITED

Group	Drainage Area in Sq. Miles	Discharge in Cu. Ft. per Second per Sq. Mile or "Run-off"	Hypothetical Velocity in Feet per Second
Northeastern	934	46.8	3.16
Middle Atlantic	2,849	44.4	4.27
Southeastern	3,615	26.2	4.92
Central	55,603	8.4	2.81
Southwestern	2,761	26.6	5.55
California	2,520	44.2	5.25
Northern Pacific slope	7,572	30.7	1.96
Ordinary average for entire U. S. A.	10,836	32.5	3.92
Adjusted average for entire U. S. A.	11,512	35.2	3.55

In order to prepare a digest of the table that would be of vice to bridge engineers, it was necessary to combine all groups of the records into a single group covering the entire United States, throw out all records of areas less than one hun miles because of their extreme variations (caused probably bursts or other abnormal conditions that affect materially the divide the records into sub-groups according to area (increasing ber of miles per group as the area increases), reducing unduly great importance of two or three observations or tions, then averaging the run-offs for each sub-group, plo

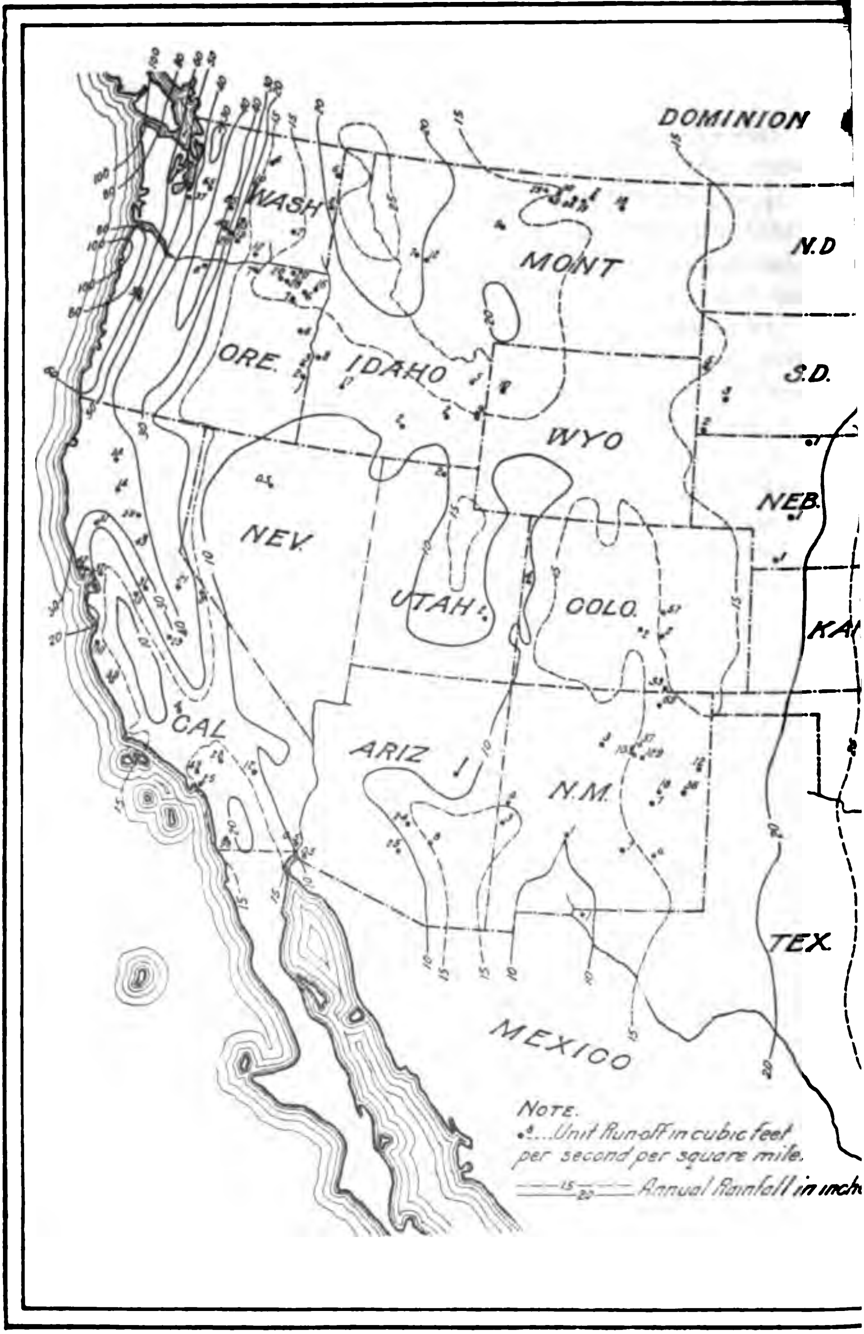
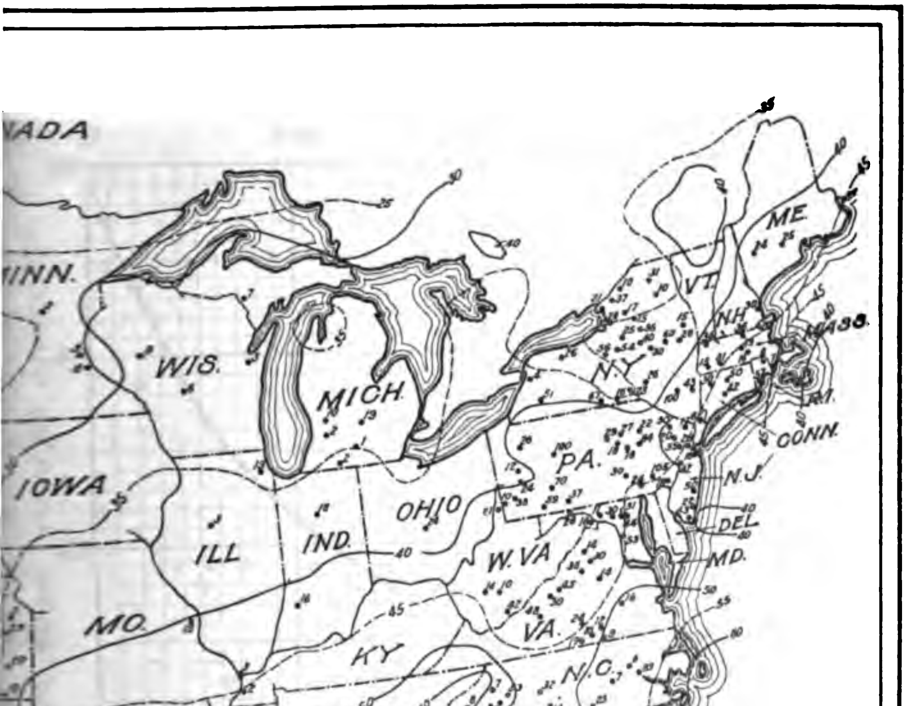


FIG. 49a. Map Showing Rainfalls



-offs Throughout the United States.


MEXICO
MAP
OF THE
UNITED
RAINFALL
RUN-OFFS

ages on a diagram, and constructing on it the enveloping curve shown in Fig. 49*b*. This will give the general average run-offs for all areas between one hundred square miles and twenty thousand square miles, based upon an average annual rainfall of thirty-five (35) inches. In applying this diagram to any particular case, one should multiply the run-off given by the curve by the ratio of the average annual rainfall of the drainage area under consideration to thirty-five (35). Although the curve is based upon the same general data as is Table 49*b*, it cannot be directly connected therewith because of numerous logical adjustments.

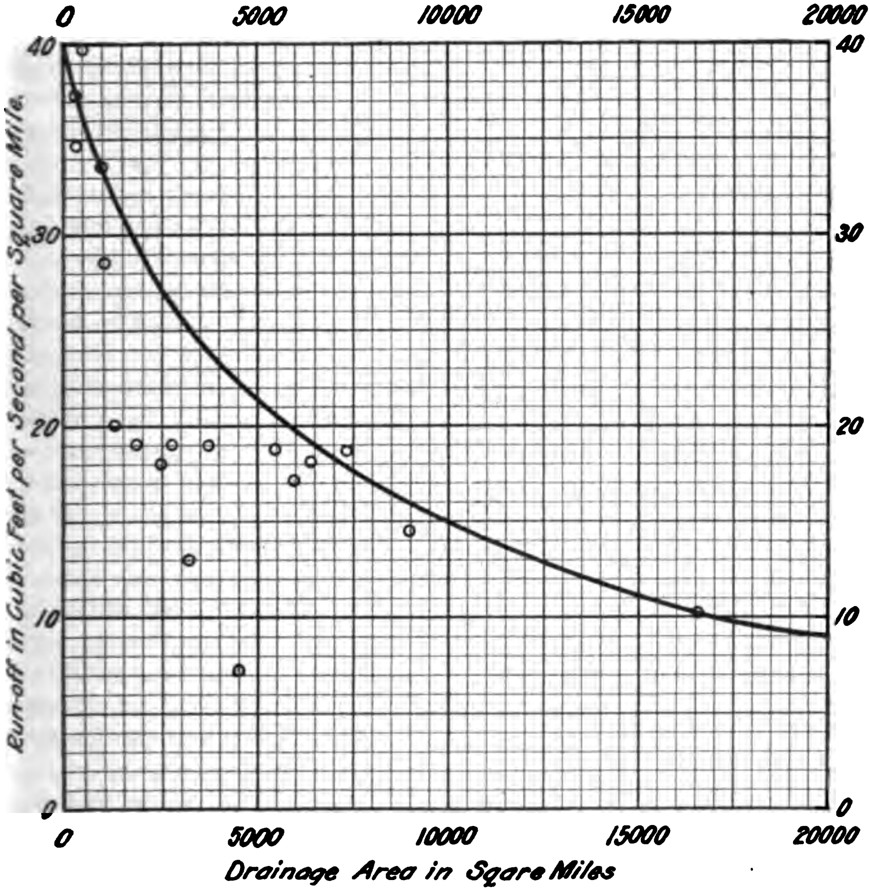


FIG. 49*b*. Average Run-offs for the United States.

While it is true that the adoption of this diagram as a standard would not provide adequately for certain abnormally great run-offs that have been recorded, it must be remembered that to make openings great enough to pass the flow from a few excessive rainfalls, which occur only a few times per century at few places in the entire United States, would be uneconomic and, therefore, bad engineering practice. If the district con-

[illegible] be deemed advisable to [illegible] though, it would not be [illegible] for any dry area where the [illegible] especially when dealing with small [illegible] liable at times to be struck by cloudbursts. [illegible] to reduce them, as before indicated, [illegible] bearing in mind, though, that the smallest [illegible] of States is twenty-five (25).

The limiting of the curve to areas of twenty thousand [illegible] a paucity of observations for very large areas; but [illegible] will do no harm, because, for large streams, other [illegible] run-off are generally the determining factors for [illegible]. In truth, it is probable that the diagram will [illegible] for drainage areas exceeding ten thousand square miles.

The probable maximum quantity of water in cubic feet [illegible] passing any section of a river can be obtained very readily by [illegible] the approximate area of water-shed in square miles, found [illegible] maps, by the run-off given in the diagram after [illegible] average rainfall of district; and the probable cross-sectional [illegible] stream at highest water can be ascertained by reference to

For cases where no previous special determination has been [illegible] the unit run-off for the watershed under consideration, but [illegible] cipitation records are available, the following method may be [illegible] for basins of moderate size. Plot the precipitation data for [illegible] storms on cross-section paper, letting the abscissæ represent the [illegible] of the storm in hours and the ordinates the average rate of [illegible] in inches, then by drawing a curve through the outlying [illegible] tative relation may be established between intensity of storms [illegible] duration. It will be observed that there is an inverse relation—[illegible] the duration of the storm the less the intensity of rainfall. Talb[illegible] mula, which is extensively used, expresses this relation thus:

$$i = \frac{360}{30 + t}$$

where i = rate in inches per hour,
and t = duration of storm in minutes.

The next step is to consider the entire basin as divided into [illegible] basins. Then, starting with the one just above the crossing, [illegible] what time would be required for a particle of water at the [illegible] of the said secondary basin to reach the site. This will give [illegible] tion of storm to consider for that secondary basin. With this [illegible] from either the diagram or the formula the rate of precipitation [illegible] termine the total precipitation per hour for the selected [illegible]

the area of the secondary basin. This will give the amount of water per hour falling on the selected basin. Plot this on a new diagram showing the relation between area and amount of water falling thereon per hour. Then repeat this operation by adding to the area of the first basin that of the one next to it, and readjust the value of storm duration to correspond. This will give a lower rate of precipitation, but extending over a longer time and more area. Plot on the diagram the amount of water falling per hour over the second zone, which includes the first and second "secondary basins," and proceed until a maximum is found. This maximum will then determine the critical storm duration and the critical area that will provide the largest amount of run-off to reach the bridge. The actual run-off will be some fraction of the total amount of precipitation, as some of the water will be absorbed by the ground and by the vegetation, and some will be lost by evaporation. The steepness of the slopes and the amount of impervious area in the water shed will also affect the run-off. The average percentage of rainfall that flows off quickly is about twenty (20), and this amount should be employed where no more accurate or probable percentage is obtainable. In some extreme cases this percentage is as low as ten (10). It is applied to the rate of precipitation just found for the critical storm period, in order to determine the time rate of run-off. As a run-off of one inch per hour flowing from one square mile is equal to 645 cubic feet per second, the run-off for any other time rate would be proportional and can readily be expressed in cubic feet per second per square mile. The flow per second from the critical zone can be obtained by multiplying the area of the zone by the run-off just found. This gives the amount of water in cubic feet passing the bridge site per second.

In the case of larger streams where precipitation and other conditions vary in the water shed, it may become necessary to resort to still another manner of estimating run-off. This method involves the determination of the probable area of stream section during flood and the accompanying mean velocity of current. As it is likely that the stream will be cross-sectioned during rather low stages of water, allowance must be made in computing the area of section for possible increased depths during flood because of scouring. That is, the bed of the stream may be unstable and subject to much change for different stages of the river. Borings will furnish information about the various kinds of material underlying the stream. With this information and a table of limiting velocities, some idea may be formed of the probable scour when a tentative velocity is ascertained. Such a table is given in the "American Civil Engineers' Pocket Book" on page 859, and is reproduced as Table 49*c*.

These values are properly for shallow streams only; for it has been found that the resistance of a material to scour increases as the water deepens. This relation is expressed by the empirical formula given on page 860 of the above mentioned "Pocket Book."

$$v_s = md^{0.64}, \qquad \text{[Eq. 14}$$

in which v_s = critical mean velocity, in feet per second, for that part o the cross-section under consideration,
m = 0.82 for fine, light, sandy silt,
= 0.90 for coarser, light, sandy silt,
= 0.99 for sandy loam,
= 1.07 for a rather coarse silt, such as débris of hard soils,
and d = depth of water in feet.

The bottom velocity will be about three-fourths of the mean velocity, o

$$v'_s = \frac{3}{4} md^{0.64} \qquad \text{[Eq. 15]}$$

To arrive at an estimate of velocity, it is necessary to measure the slope of the stream. The flood line, if a series of reliable high-water marks for a single flood can be found, should preferably be used; otherwise the average slope of the bed will have to suffice. With this information and the other data from the cross-section of the stream, Kutter's well-known formula, Equation 17, may be employed to arrive at a tentative value for velocity. In applying that formula, better results may be obtained by considering alone the cross-section of the main channel with a particular value of n consistent with actual conditions in the said channel. The coefficient n would be larger for the side flow over a low bank than in the channel on account of vegetation and other obstructions. Having determined a tentative mean velocity for the channel portion of the cross-section, the maximum surface velocity which occurs over the deepest portion of the stream may be approximated by multiplying the said mean velocity by five-fourths. Surface velocities in other portions of the cross-section may be assumed to be proportional to the square root of the depths at those places. The mean velocity at any one of these portions would be about nine-tenths of the surface velocity at that point, while the bottom velocity would approach three-fourths of the mean velocity or two-thirds of the surface velocity. This will give in conjunction with the table of limiting velocities an idea of what material must be

TABLE 49c

SCOURING OF RIVER BEDS

Material	Bottom Velocity in Feet per Second
Soft earth	0.25
Soft clay	0.50
Sand	1.00
Gravel	2.00
Sea pebbles (1.06" diameter)	2.20
Brickbats (4.76 cu. in.)	2.25 to 2.50
Slate (9.06 cu. in.)	2.75 to 3.00
Broken stone	4.00

reached before scouring ceases. This information permits the plotting of a tentative cross-section for flood conditions, from which a new value for the hydraulic radius may be obtained and a revision of the mean velocity computed for the main channel. Velocities for other portions of the cross-section may be found either by Kutter's formula or roughly, as before mentioned, by assuming them to be proportional to the square root of the depth.

Having arrived at an estimate of probable maximum run-off to provide for, the next step is to design an opening that will pass the required amount of water without damage to the structure or to adjacent works or properties. Due regard must be had for local conditions and for possible future development. The *desideratum* is to secure the highest discharge efficiency that the local conditions will permit. Most rivers in their natural state have low discharge efficiencies. An increase in efficiency usually means an increase in the hydraulic radius. If this can be secured, less area will be needed, and, consequently, a shorter and less expensive structure. The limiting velocities for banks, sides, and bottom can be fixed to conform with the scouring resistance of the materials composing them; and then an allowable mean velocity may be computed. It is possible to increase the resistance to scour by rip-rapping, either using willow mattresses or employing some of the other protective measures referred to in Chapter XLIV. The possibility of straightening and clearing out the channel for some distance above and below the bridge site should be given careful consideration, as the discharge capacity can be increased by so doing.

Having decided on an allowable mean velocity, it next becomes necessary to know how much head or slope will be required to produce the said velocity. For this purpose the Chezy formula,

$$v = C\sqrt{rs}, \qquad \text{[Eq. 16]}$$

may be employed,

where v = velocity in feet per second,
C = coefficient evaluated by Kutter's formula,
r = hydraulic radius,
and s = sine of slope.

The slope would apply to a channel unobstructed with piers. The effect of these is to back the water up somewhat immediately above them, thus producing a greater slope for the intermediate space. This amount of backing up or increase of head can be ascertained by considering the discharge between the piers as composed of two elements, viz., the discharge through a submerged orifice, having a width equal to the distance between piers, and a depth equal to that below them, and a flow over a weir of length equal to the distance between the piers and a head equal to the difference in depths above and below them.

The possibility of levees being constructed or extended must also be considered. The usual effect of levees is to contract the width of the waterway and increase the depth, producing a higher velocity and augmenting the scour. For the protection of the bridge, the levees should tie into the abutments and extend down stream so far that the discharge thereof when released from the contracted channel will not scour holes too close to the bridge substructure. A case of this kind once occurred at a crossing of the Atchafalaya River. The bridge, as originally planned, consisted of a draw span with a fixed span at each end of it. Levees had been constructed along both banks of the river. One of them, however, stopped some distance above the bridge. When a flood was on, the rush of water from the contracted channel, escaping to the wide, unprotected bottoms, set up a scouring action which weakened the bank and caused a large earth slide that resulted in a tipping of one of the piers.

As an example of the determination of a waterway, let us assume the following data for a crossing and apply to it the preceding formulæ and methods:

Let the location chosen be in the State of Missouri near the mouth of a river similar, for instance, to the Gasconade. Of course, it would be much better to take the true data for that river rather than to adopt hypothetical data for a hypothetical stream; but, unfortunately, the author has no record of the hydraulics of the Gasconade; hence he has done the best he could to prepare a harmonious set of figures based upon his practical experience in connection with American rivers.

Width of watershed at crossing................. = 40 miles.
Width of same, determined by an old survey, at a distance of one hundred (100) miles up stream.. = 20 miles.
Intermediate widths to be directly interpolated.
Total length of watershed above crossing......... = 130 miles.
Width of river at a fairly low stage of water when the survey was made...................... = 450 feet.
Maximum depth of water at the same time at a point about eighty (80) feet from the left bank...... = 4 feet.
Average depth of water...................... = 2.8 feet.
Greatest observed surface velocity at crossing when survey was made.......................... = 1.5 miles per hour.
Side-slope on left bank where the rock is exposed.. = one in two.
Side-slope on the right bank of stream, from water's edge to top of bank...................... = one in four.
Height of right bank above surface of water when survey was made......................... = 6 feet.
Width of level portion of top of right bank....... = 50 feet.

Falling slope back of right bank for a distance of five hundred (500) feet averages one-half (½) of one per cent.

Then comes a dry, level slough two hundred (200) feet wide; and, finally, there is a rising grade of three-quarters (¾) of one per cent for a thousand feet or more.

Average slope of river for first ten miles up-stream is one and a half (1½) feet per mile; and in each ten-mile stretch beyond it increases regularly by one foot to the mile.

Borings near water's edge on the right side, at time of survey, showed four (4) feet of silt, twelve (12) feet of sand, then gravel that was fine at first but increasing in coarseness gradually with the depth, the vertical measurements being made from the elevation of the water.

Material of the low bank and of the flat is a sandy loam that was evidently deposited by the river, but across the slough it is harder, showing that it has been washed down by rain from the adjacent higher land. The low bank and the flat are covered with vegetation that will offer considerable resistance to scour. The crossing is near the middle of a long, easy bend in the stream, and the current at high water impinges against the rocky bank. Records of high water are very meagre, all that could be learned being that at times the elevation was about a foot higher than the top of the right bank. No reliable records concerning floods were obtainable.

Rainfall is about thirty-five (35) inches per annum.

In so far as the information permits, we shall apply to the solution of this problem the various suggested methods in the order of their presentation. For convenience we shall tabulate our primary data and the obvious deductions therefrom for ready substitution in the various formulæ.

At time of survey:

Area of watershed = 3,300 square miles = 2,112,000 acres.
Mean annual precipitation = 35 inches.
Maximum depth = 4 feet.
Average depth = 2.8 feet.
Width at time of survey = 450 feet.
Area of section at time of survey = 1,260 square feet.
Greatest observed surface velocity at crossing when survey was made = 1.5 miles per hour, or 2.2 feet per second.
Mean velocity = 0.8 × 2.2 = 1.76 feet per second.

Sine of slope $= \frac{1.5}{5280} = .000284.$ $\sqrt{.000284} = .0168.$

Hydraulic radius = 2.8 feet, nearly. $\sqrt{2.8} = 1.67.$

Coefficient "n" deduced from observed velocity by Kutter's formula = 0.028 for low stages.

$Q = 1{,}260 \times 1.76 = 2{,}220$ cubic feet per second.

Unit run-off at time of survey $= \frac{2,218}{3,300} = 0.672$ cubic feet per secon per square mile.

The first method is that of using Dun's Drainage Table. For a drainage area of 3,300 square miles and a rainfall of 35 inches per annum, whic conforms with conditions in Missouri, we find, by interpolation, that th waterway required is 11,120 square feet.

We shall next take up the second set of formulæ giving the volum of discharge.

Fanning's:

$$Q = 200 \times (3,300)^{\frac{5}{6}} = 171,000 \text{ cu. ft. per sec. at bridge site.}$$

Burkli-Ziegler's:

$$q = 0.625 \times 0.5\sqrt[4]{\frac{.1}{2,112,000}} = 0.0046 \text{ cu. ft. per sec. per acre.}$$

or $Q = 0.0046 \times 2,112,000 = 9,715$ cu. ft. per sec. at bridge site.

Here we had to assume the intensity of rainfall and the average slope of the watershed.

McMath's:

$$Q = 0.2 \times 0.5\sqrt[5]{1. \times 2112000^4} = 11,500 \text{ cu. ft. per sec. at bridge site.}$$

Kuichling's:

$$q = \frac{44,000}{3,300 + 170} + 20 = 32.7 \text{ cu. ft. per sec. per sq. mile.}$$

$$Q = 3,300 \times 32.7 = 108,000 \text{ cu. ft. per sec. at bridge site.}$$

Murphy's:

$$q = \frac{46,790}{3,300 + 320} + 15 = 27.9 \text{ cu. ft. per sec. per mile.}$$

$$Q = 3,300 \times 27.9 = 92,000 \text{ cu. ft. per sec. at bridge site.}$$

The C. B. & Q. Ry.:

$$Q = \frac{3,000M}{3 + 2\sqrt{M}} = \frac{3,000 \times 3,300}{3 + 2\sqrt{3,300}} = 84,000 \text{ cu. ft. per second at bridge site.}$$

The wide range of variation in these results should serve to put the engineer on his guard in utilizing such formulæ. The Burkli-Ziegler and McMath formulæ are frequently adopted for determining the run-off from small areas when designing sewer systems, but they have only a restricted application and should not be employed for large areas. The author has included these in the list so that he may warn the reader of their limited application.

The next method is that of applying the curve in Fig. 49*b*, which gives for an area of 3,300 square miles a run-off of about twenty-five (25) cubic feet per second per square mile. This makes

[illegible] the following table

[illegible]	
Hours	Minutes
6.67	400
5.71	343
7.50	450
6.67	400
6.00	360

[illegible] table are based upon some [illegible] and upon engineering [illegible] would increase with the average

[illegible] of rainfall gives the following

[illegible] in Inches per Hour [illegible] Formula	Amount of Water Falling on Zone in Inch-Miles per Hour
0.84	638
0.47	677
0.29	670
0.22	660
0.18	594

[illegible] that the second case will give [illegible] zone per hour, and, therefore,

will correspond to the condition that will involve the largest amount o water passing the bridge site at any time. The area of this zone is 1,440 square miles and the rainfall on it is 0.47 inch per hour. Of this only twenty (20) per cent, or 0.094 inch per hour, will pass promptly down stream, the rest being retained by the soil, vegetation, ponds, evaporation, etc. One inch per hour flowing from a square mile corresponds to 645 cubic feet per second, hence the run-off per square mile will be 645 × 0.094 = 61 cubic feet per second. As there are 1,440 square miles in the zone, the total run-off will be 1,440 × 61 = 87,840 cubic feet pe second.

It is to be noted that although this method is a rather rough approximation, being based on assumed average velocities for the different reaches and upon a general average ratio of run-off to rainfall, which average varies with the perviousness of the soil, the character of the vegetation and the steepness of the surrounding country, the assumptions were all very carefully made; and, consequently, the checking within about si (6) per cent, which it gives when compared with the total run-off computed from the diagram, is not surprising.

The next method is that of approximating the cross-section of the river at flood stages and applying the formula for mean velocity,

$$v = C\sqrt{rs}$$

where v = mean velocity at cross-section,
r = hydraulic radius,
s = sine of slope,
and C = a coefficient to be evaluated by Kutter's Formula, which, for ready reference, is here quoted.

$$C = \left\{ \frac{\dfrac{1.811}{n} + 41.6 + \dfrac{0.00281}{s}}{1 + \left(41.6 + \dfrac{0.00281}{s}\right)\dfrac{n}{\sqrt{r}}} \right\}, \qquad \text{[Eq. 17}$$

in which n is the coefficient of roughness varying from 0.025 to 0.045 for rivers.

For convenience let us call the elevation of the top of the convex bank 100.0.

Then the elevation of the observed high-water mark will be 101.0. It is first desired to find the probable discharge of the stream when the flood line is at this elevation. When making the computations, let us consider the main channel by itself, ignoring temporarily the scour effect. Owing to the slope of the banks, it will have a greater width at flood than at low water. For the observed flood line, having an elevation of 101.0, the width is 488 feet and the maximum depth is 11 feet. We then have the following:

$$\text{Area} = 1{,}260 + 7\left(\frac{488 + 450}{2}\right) = 4{,}543 \text{ square feet.}$$

Wetted perimeter = 491 feet.

Hydraulic radius $= \frac{4{,}543}{491} = 9.25$ feet. $\sqrt{9.25} = 3.04$.

Sine of slope $= \frac{1.5}{5{,}280} = 0.000284$. $\sqrt{.000284} = 0.0168$.

Coefficient of roughness, $n = 0.028$.

Substituting in Equation 17 gives $C = 78.8$; hence

$v = 78.8 \times 3.04 \times 0.0168 = 4.02$ feet per second, and

$Q = 4.02 \times 4{,}543 = 18{,}263$ cubic feet per second (provisional).

The maximum surface velocity at the deep part of the channel would be $5/4 \times 4.02 = 5.03$ feet per second. The bottom velocity at this section would be $2/3 \times 5.03 = 3.35$ feet per second.

Referring to the table of limiting velocities, it is seen that, as the stage of the river approaches a flood elevation, scouring is to be expected. This rise will enlarge the cross-section, causing a higher velocity, which results in further scouring and in an additional enlargement of the stream-section until equilibrium is established between the increasing velocity and the augmenting resistance to scour due to the greater depth. It, therefore, becomes necessary to approximate the new cross-section in order to find the probable flood discharge. To do this, the depth of scouring must be expressed in terms of the rise in the stage of the river. That there is a relation between these two phenomena will be better appreciated when the sequence of intermediate dependent factors is traced out.

For a given stage of water, after the bed has become stable, the bottom velocity must be such that neither silting nor scouring takes place. As before indicated, this critical velocity has been found to increase with the depth of water; and for the mid-channel it may be estimated by one of the following formulæ, derived from Equation 15:

For fine, light, sandy silt,

$$v'_s = 0.615d^{0.64} \qquad \text{[Eq. 18]}$$

For coarse, light, sandy silt,

$$v'_s = 0.675d^{0.64} \qquad \text{[Eq. 19]}$$

For a sandy loam,

$$v'_s = 0.742d^{0.64} \qquad \text{[Eq. 20]}$$

For coarse silt, such as the débris of hard soils,

$$v'_s = 0.803d^{0.64}, \qquad \text{[Eq. 21]}$$

in which v'_s = critical bottom velocity in feet per second,

and d = depth of water in feet at mid-channel.

For equilibrium the actual bottom velocity at mid-channel must equal the critical velocity for the given depth at the same place. That is, if v'_c represents the actual mid-channel bottom velocity, then

$$v'_c = v'_s. \qquad \text{[Eq. 22]}$$

For scouring to occur, the actual velocity must increment, $\Delta v_s'$. This requires that the mean velocity for the cross-section be increased by some increment, Δv. As long as the of the water surface remains constant, Δv can only occur by the radius receiving an increment, Δr. This in turn means that the between the increment of area to the stream section and the incr of length to the wetted perimeter must increase faster than the between the area and the wetted perimeter. That is,

$$\frac{\Delta A}{A} > \frac{\Delta P}{P}.$$

In this inequality,

ΔA = increment to area, composed of two parts, ΔA_1 being the portion due to rise in stage of river, and ΔA_2 the portion due to scour;

or $\Delta A = \Delta A_1 + \Delta A_2$.

A = area of stream section at the time of observation.

ΔP = increment to wetted perimeter, composed of three parts, ΔP_1 and ΔP_2 being the portions due to rise in water level, and ΔP_3 the portion due to scour;

or $\Delta P = \Delta P_1 + \Delta P_2 + \Delta P_3$,

and P = wetted perimeter at the time of observation.

Now ΔA is first caused by a rise in the river stage, which is thus to be the primary cause for the chain of subsequent readjustments stream factors. An approximate quantitative relation between factors can be established by the following considerations:

The tendency is for the stream to approach a form of cross-section in which it encounters the least resistance, or, in other words, for wetted perimeter, though changing, to remain a minimum relative to area; which means that the hydraulic radius continues to approach maximum value until equilibrium is reached. This involves a cu of the river bed, because such curving increases the increment to area faster than it does the increment to the perimeter.

If the observed stage of water be given an increment, ΔS, the section will receive an increment to its area which produces an ment in the wetted perimeter; then the new hydraulic radius will $r + \Delta r$. That is,

$$\frac{A + \Delta A}{P + \Delta P} = r + \Delta r$$

For scouring to take place, Δr must be positive, because the cannot increase otherwise. If the hydraulic radius remain then

$$\frac{\Delta A}{\Delta P} = \frac{A}{P'}, \qquad \text{[Eq. 25]}$$

and no scouring results.

As previously mentioned, ΔA is composed of two parts. The upper portion, ΔA_1, can readily be expressed in terms of three factors, viz.,

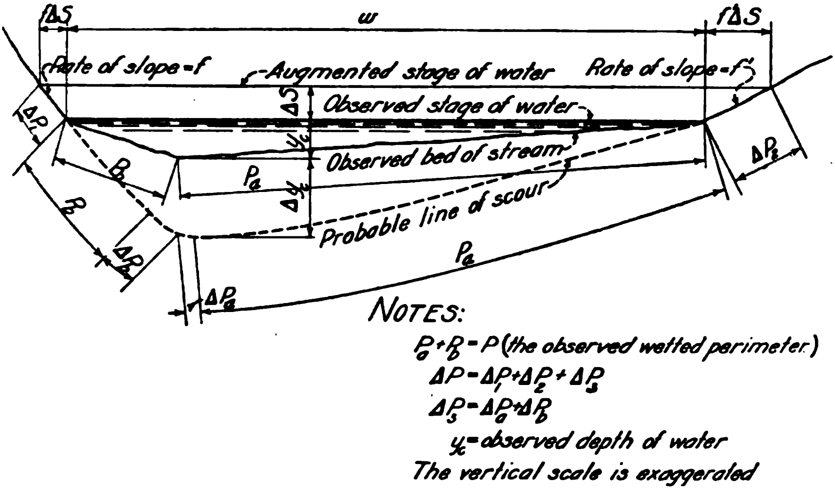


FIG. 49c. Cross-section of Stream.

ΔS, the original width w, and the slopes of the bank f and f'; and the lower portion in terms of perimeter and scoured depth.

From Fig. 49c it is seen that

$$\Delta A_1 = \Delta S\left(w + \frac{f}{2}\,\Delta S + \frac{f'}{2}\,\Delta S\right), \qquad \text{Upper portion. [Eq. 26]}$$

$$\Delta A_2 = \frac{2P_a\,\Delta y_c}{3} + \frac{2P_b\,\Delta y_c}{3} = \frac{2P\,\Delta y_c}{3}, \qquad \text{Lower portion. [Eq. 27]}$$

then $$\Delta A = \Delta A_1 + \Delta A_2 = \Delta S\left(w + \frac{f}{2}\,\Delta S + \frac{f'}{2}\,\Delta S\right) + \frac{2P\,\Delta y_c}{3}. \qquad \text{[Eq.28]}$$

Also $$\Delta P_1 = \sqrt{\overline{\Delta S}^2 + f^2\,\overline{\Delta S}^2} = \Delta S\sqrt{1 + f^2}. \qquad \text{[Eq. 29]}$$

$$\Delta P_2 = \sqrt{\overline{AS}^2 + f'^2\,\overline{\Delta S}^2} = \Delta S\sqrt{1 + f'^2}. \qquad \text{[Eq. 30]}$$

$$\Delta P_3 = \frac{2\,\overline{\Delta y_c}^2}{3}\left(\frac{P}{P_a\,P_b}\right). \qquad \text{[Eq. 31]}$$

This last equation may be derived by the following process:

Assume that the original bed is sensibly flat and nearly horizontal, that it is scoured out to some depth at mid-channel, as Δy_c, which is relatively large as compared with the original depth y_c, and that the new bed-

[illegible] by the dotted curved lines [illegible] curves may be taken as parabolic [illegible] determined by the approximate formula [illegible] American Civil Engineers' Pocket Book [illegible]

$$s = l\left(1 + \frac{8h^2}{3l^2} - \frac{32h^4}{5l^4} + \text{etc.}\right) \text{ for symmetrical arc.}$$

As $\frac{h}{l}$ will be a small fraction, the fourth and higher powers may properly be dropped. Then for the half symmetrical arc (using the appropriate symbols of this chapter), we have

$$\text{Length of arc for } P_a = P_a\left\{1 + \left(\frac{8}{3}\right)\frac{\overline{\Delta y_e}^2}{4P_a^2}\right\} = P_a + \frac{2}{3}\left(\frac{\overline{\Delta y_e}^2}{P_a}\right)$$

subtracting P_a from both members of the equation there is obtained

$$\Delta P_a = \frac{2}{3}\frac{\overline{\Delta y_e}^2}{P_a}$$

similarly

$$\Delta P_b = \frac{2}{3}\frac{\overline{\Delta y_{e'}}^2}{P_b}$$

and

$$\Delta P_3 = \Delta P_a + \Delta P_b = \frac{2}{3}\,\overline{\Delta y_e}^2\left(\frac{1}{P_a} + \frac{1}{P_b}\right) = \frac{2}{3}\,\overline{\Delta y_e}^2\left(\frac{P}{P_a\,P_b}\right)$$

Other assumptions as to original conditions of stream-bed and ratio of scour to original depth might be made, giving somewhat different results than those shown in Equation 35; but as the value of ΔP_3 is relatively insignificant in all cases, no attempt at refinement is necessary.

Then

$$\Delta P = \Delta P_1 + \Delta P_2 + \Delta P_3$$

$$= \Delta S\,\sqrt{1+f^2} + \Delta S\,\sqrt{1+f'^2} + \frac{2}{3}\,\overline{\Delta y_e}^2\left(\frac{P}{P_a\,P_b}\right).$$

Substituting these values of ΔA and ΔP in the previous formula for hydraulic radius, the following expression is obtained for the new hydraulic radius:

$$\frac{A + \Delta S\left(w + \frac{f}{2}\,\Delta S + \frac{f'}{2}\,\Delta S\right) + \frac{2}{3}P\,\Delta y_e}{P + \Delta S\,\sqrt{1+f^2} + \Delta S\,\sqrt{1+f'^2} + \frac{2}{3}\Delta y_e^2\left(\frac{P}{P_a P_b}\right)}$$

$$= r + \Delta r = \frac{A}{P} + \Delta r.$$

It is next necessary to express Δr in terms of Δv. Using Kutter's Formula, and remembering that n and s are constants and known for any particular case, there is obtained a relation between v and r from which, by differentiation, the relation between Δv and Δr can be established, thus:

$$v = C\sqrt{rs}, \text{ where } C = \left\{ \frac{\dfrac{1.811}{n} + 41.6 + \dfrac{.00281}{s}}{1 + \left(41.6 + \dfrac{.00281}{s}\right)\dfrac{n}{\sqrt{r}}} \right\}$$

As the numerator of this fraction is constant, it can be replaced with the single symbol, k. In the denominator let $j = \left(41.6 + \dfrac{.00281}{s}\right)n$, then the equation may be written thus:

$$C = \frac{k}{1 + \dfrac{j}{\sqrt{r}}} = \frac{k\sqrt{r}}{\sqrt{r} + j}, \qquad \text{[Eq. 38]}$$

then $$v = \frac{k\sqrt{r}}{\sqrt{r}+j}\sqrt{r}\sqrt{s} = \frac{k\,r}{\sqrt{r}+j}\sqrt{s}; \qquad \text{[Eq. 39]}$$

but as the $\sqrt{s}$ is a constant, $k\sqrt{s}$ can be replaced by K;

then $$v = \frac{Kr}{\sqrt{r}+j}. \qquad \text{[Eq. 40]}$$

By differentiation, it is seen that

$$\Delta v = \frac{(\sqrt{r}+j)K - Kr\left(\dfrac{1}{2}r^{\frac{1}{2}}\right)}{(\sqrt{r}+j)^2}\Delta r = K\frac{\dfrac{1}{2}\sqrt{r}+j}{r + 2j\sqrt{r} + j^2}\Delta r \qquad \text{[Eq. 41]}$$

or $$\Delta r = \frac{r + 2j\sqrt{r} + j^2}{K\left(\dfrac{1}{2}\sqrt{r}+j\right)}\Delta v. \qquad \text{[Eq. 42]}$$

But from numerous observations it is known that $v = \dfrac{6}{5}v_c'$, hence

$$\Delta v = \frac{6}{5}\Delta v_c', \qquad \text{[Eq. 43]}$$

and, at the time equilibrium is re-established for the new flood line,

$$v'_c + \Delta v'_c = v'_s + \Delta v'_s. \qquad \text{[Eq. 44]}$$

However, before the rise in the stream occurred

$$v'_c = v'_s, \qquad \text{[Eq. 45]}$$

therefore $$\Delta v'_c = \Delta v'_s \qquad \text{[Eq. 46]}$$

$$\Delta v = \frac{6}{5}\Delta v'_s$$

By differentiating the expression for critical velocity,

$$v'_s = md^{0.64},$$

a value for $\Delta v_s'$ in terms of Δy_c and ΔS is found thus,

$$\Delta v'_s = 0.64\, md^{-0.36}\Delta d,$$

$$\text{but } \Delta d = \Delta y_c + \Delta S,$$

$$\text{hence } \Delta v_s' = \frac{0.64\, m}{d^{0.36}}(\Delta y_c + \Delta S) = \Delta v_s'$$

It has been seen that

$$\Delta v = \frac{6}{5}\Delta v_s' = \frac{6}{5}\Delta v_s' = \frac{6}{5}\left\{\frac{0.64\, m}{d^{0.36}}(\Delta y_c + \Delta S)\right\}$$

Substituting this value in the equation for Δr. there is obtained

$$\Delta r = \left(\frac{r + 2j\sqrt{r} + j^2}{K\left(\frac{1}{2}\sqrt{r} + j\right)}\right) \times \frac{6}{5}\left\{\frac{0.64\, m}{d^{0.36}}(\Delta y_c + \Delta S)\right\} =$$

$$\frac{0.77\, m}{d^{0.36}}(\Delta y_c + \Delta S)\left(\frac{r + 2j\sqrt{r} + j^2}{K\left(\frac{1}{2}\sqrt{r} + j\right)}\right).$$

Then substituting this value for Δr in Equation 37 for the ne radius, there results an equation in which Δy_c is expressed as function of ΔS, the other terms being known and having prede numerical values, viz.:

$$\frac{A + \Delta S\left(w + \frac{f}{2}\Delta S + \frac{f'}{2}\Delta S\right) + \frac{2}{3}P\,\overline{\Delta y_c}}{P + \Delta S\sqrt{1+f^2} + \Delta S\sqrt{1+f'^2} + \frac{2}{3}\overline{\Delta y_c^2}\left(\frac{P}{P_a P_b}\right)} =$$

$$\frac{A}{P} + \frac{0.77\, m}{d^{0.36}}(\Delta y_c + \Delta S)\left(\frac{r + 2j\sqrt{r} + j^2}{K\left(\frac{1}{2}\sqrt{r} + j\right)}\right)$$

As the term involving $\overline{\Delta y_c^2}$ is practically insignificant on acco smallness of its coefficient, in comparison with the other which it is added, it may be dropped, making Equation

$$\frac{A + \Delta S\left(w + \frac{f}{2}\Delta S + \frac{f'}{2}\Delta S\right) + \frac{2}{3}P\Delta y_c}{P + \Delta S\left(\sqrt{1+f^2} + \sqrt{1+f'^2}\right)} =$$

$$\frac{A}{P} + \frac{0.77\,m}{d^{0.36}}(\Delta y_c + \Delta S)\left\{\frac{r + 2j\sqrt{r} + j^2}{K\left(\frac{1}{2}\sqrt{r} + j\right)}\right\} \qquad \text{[Eq. 54]}$$

This is the desired equation.

For the particular problem in hand the following numerical values are substituted in the foregoing formula.

$A = 1{,}260$ square feet
$P = 450$ feet $\qquad P_a = 370$ feet and $P_b = 80$ feet
$w = 450$ feet
$n = 0.028$
$s = 0.000284$ $\qquad \sqrt{s} = 0.0168$
$r = 2.8$ $\qquad \sqrt{r} = 1.67$
$f = 2$ $\qquad f' = 4$
$m = 0.71$ (An average for the range of values given by equations 18 to 21, inclusive.)

$$K = 0.0168 \times \left(\frac{1.811}{.028} + 41.6 + \frac{.00281}{.000284}\right) = 0.0168\,(64.7 + 41.6 + 9.9) = 1.95$$

$$j = \left(41.6 + \frac{.00281}{.000284}\right) \times .028 = 51.5 \times .028 = 1.44. \qquad j^2 = 2.07$$

$d = 4$ feet $\qquad d^{0.36} = 1.65$
$\Delta S = 7$ feet.

Substituting these values in Eq. 54 and solving, we find for the depth of scour, Δy_c, a value of 11.9 feet. As there is an old saying among those who are familiar with silt-bearing rivers to the effect that for each foot of rise there are about two feet of scour, this result appears to be correct. Such a scour, however, would involve cutting down to the gravel, but the superior resistance of this material would interfere, and hence it is probable that the scouring would extend horizontally, possibly over a large portion of the width of the bed.

Referring now to Eq. 28 and substituting therein 7 for ΔS and 11.9 for Δy_c, we find the increment of area to be 6,867 square feet, and adding to this the original area of cross-section, 1,260 square feet, gives 8,127 square feet as the total area of the new cross-section of the river proper.

The new wetted perimeter is found from Eq. 36 by substituting therein the same values of ΔS and Δy_c, making the increment about 46 feet and the total 496 feet.

$$\text{The hydraulic radius is } \frac{8{,}127}{496} = 16.38 \text{ feet,}$$

$$\therefore \sqrt{r} = \sqrt{16.38} = 4.04$$

Sine of slope = 0.000284,

$n = .028$, as before.

Substituting these figures in the

$$C = 85.5,$$

hence $v = 85.5 \times 4.04 \times 0.0168 = 5.8$

The discharge from the main

$Q = 5.8 \times 8127 = 47{,}137$ cubic

The next step will be to estimate the discharge the old slough. It is stated that there is considerable and on the adjacent slopes, so that it will be necessary coefficient of roughness, hence n is taken at 0.035.

Area = 2,442 square feet.

Wetted perimeter = 1,217 feet.

$$\text{Hydraulic radius} = \frac{2442}{1217} = 2. \quad \sqrt{2} = 1.41$$

Sine of slope = 0.000284. $\sqrt{.000284} = 0.0168$

Substituting these values in the formula gives $C = 45.5$;

$v = 45.5 \times 1.41 \times 0.0168 = 1.08$ feet per second.

$Q = 1.08 \times 2442 = 2637$ cubic feet per second.

The total discharge = 2637 + 47,137 = 49,774 cubic feet

From this we conclude that the minimum discharge provided for should not be less than the foregoing amount. hand, the critical storm method shows that provision should pass about 88,000 cubic feet per second, and the "curve of indicates that a flow of 82,500 cubic feet per second is the The C. B. & Q. formula, previously quoted, gives 84,000 formula 92,000. Hence the further conclusion is reached served high-water line is not that of extreme floods. To damage to the bridge or adjacent properties, provision for a discharge of 82,500 cubic feet per second.

The probable extreme flood line will next be determined assume an additional height of four feet, making the extreme flood line 105.0. Increment to the area of 4(488 + 4) = 1,968 square feet.

Total area = 8127 + 1968 = 10,095 square feet.

Wetted perimeter = 496 + 9 = 505 feet.

$$\text{Hydraulic radius} = \frac{10{,}095}{505} = 20; \text{ and } \sqrt{20} = 4.47.$$

Substituting these values in the formula gives $C = 87.8$;

$v = 87.8 \times 4.47 \times 0.0168 = 6.59$ feet per second, and

$Q = 6.59 \times 10{,}095 = 66{,}526$ cubic feet per second

main channel.

For the slough we shall assume that the brush and other vegetation will prevent scour, hence we shall have the following:

Increment to the area = 5934.

Total area = 5934 + 2442 = 8376 square feet.

Wetted perimeter = 1217 + 533 = 1750 feet.

Hydraulic radius $\frac{8376}{1750} = 4.78$. $\sqrt{4.78} = 2.19$. $n = 0.035$.

Substituting these values in the formula gives $C = 56.7$; hence

$v = 56.7 \times 2.19 \times .0168 = 2.09$ feet per second, and

$Q = 2.09 \times 8376 = 17{,}506$ cubic feet per second.

Total = 66,526 + 17,506 = 84,032 cubic feet per second.

This volume is somewhat in excess of the assumed amount; hence it will be conservative to take 105.0 as the elevation of the extreme flood line. This gives a maximum depth of water in the channel of twenty-seven feet and in the slough one of seven and a half feet, while the extreme width of flood will be about 2,250 feet, and the total area of waterway, 18,470 square feet.

If all this flood were confined to the main channel by building a levee along the low bank, a calculation similar to the preceding shows that the flood line would be raised to about elevation 108.0.

This would require a levee at least nine feet high. It is hardly probable that such a levee along the low bank would be justified, unless the land were valuable and worth protecting. It then becomes a question whether to build and maintain for railroad purposes a solid embankment across the slough and the adjoining low lands, or to leave an opening at the said slough and put in a trestle. The length of such a trestle would depend on how high the flood line might be raised without serious injury. If it be permissible to increase the extreme high water to elevation 106.0, we find by interpolation that the main channel would carry about 72,000 cubic feet per second. This leaves 10,500 cubic feet per second to be carried through the slough. A four-hundred-foot trestle will provide an opening of about 3,340 square feet, while the velocity will approximate 3.0 feet per second, which gives a discharge capacity of some 10,020 cubic feet per second, which is almost exactly right. However, the bents of the trestle will obstruct the flow somewhat, hence it is not desirable to limit the opening to a bare sufficiency. This layout gives a total waterway for the entire crossing of about 13,930 square feet with a flood line at elevation 106.0. For an unobstructed flow, the area as previously noted would be 18,470 square feet with the flood line at elevation 105.0. With the flood confined to the main channel, the area becomes about 11,600 square feet and the flood line rises to elevation 108.0. It is thus seen that the most efficient discharge section is the restricted area. In this connection it is to be noted that Dun's Drainage Table in the "Missouri Column" gives, by interpolation, for a drainage area of 3,300 square miles, a required area of waterway of 11,123 square feet, which is some-

what less than the area of the opening provided by the main channel and the four-hundred-foot trestle at the slough, showing that the proposed layout is satisfactory.

This shows a substantial agreement between values derived from Dun's Table, the unit run-off curve, the critical storm method, the method of determining waterways from velocities estimated by Kutter's Formula, and the C. B. & Q. Formula, while the results derived from the Murphy Formula are not out of range. Fanning's Formula calls for over one hundred (100) per cent excess area for waterway, while Kuichling's Formula indicates about thirty (30) per cent excess, as compared with the figures obtained by means of Fig. 49*b*.

In order to test further the C. B. & Q., the Murphy, and the Kuichling formulæ so as to see how they agree with the diagram method for small areas, it will be well to assume, as at the beginning of this chapter, a drainage area of 250 square miles.

C. B. & Q. Formula:

$$Q = \frac{3000 \times 250}{3 + 2\sqrt{250}} = 21{,}670 \text{ cubic feet per second.}$$

Murphy Formula:

$$Q = 250\left(\frac{46{,}790}{250 + 320} + 15\right) = 24{,}270 \text{ cubic feet per second.}$$

Kuichling Formula:

$$Q = 250\,q = 250\left(\frac{44{,}000}{250 + 170} + 20\right) = 31{,}190 \text{ cubic feet per second.}$$

The diagram gives

$$Q = 38 \times 250 = 9{,}500 \text{ cubic feet per second.}$$

As the run-offs to fit the C. B. & Q., the Murphy, and the Kuichling formulæ are respectively 87, 97, and 125, and as the former figure exceeds all but 36 of the 447 records in the table of the A. R. E. A., and the latter all but 15 of them, it is evident that none of the formulæ can be considered satisfactory. Moreover, the 36 exceptional areas of the table exceeding a run-off of 87 have an average drainage area of only 138 square miles.

In view of the foregoing, the author feels justified in advising his readers to place no reliance whatsoever on any of the formulæ for area and discharge of streams, but to adopt instead as a standard Dun's Tables and the Run-Off Diagram presented in this chapter—bearing in mind, however, that when the anticipated area and discharge are unusually high, every practicable investigation should be made so as to determine their probable maximum values, following the methods herein explained.

CHAPTER L

REQUIREMENTS OF THE UNITED STATES GOVERNMENT FOR BRIDGING NAVIGABLE WATERS

THE determination of what are and what are not "navigable waters" in the United States has been made by various decisions of the Supreme Court, from among which the following have been chosen as the most explicit concerning the question:

Mr. Justice Field states thus:

> "Those rivers must be regarded as public navigable rivers in law which are navigable in fact. And they are navigable in fact when they are used, or susceptible of being used, in their ordinary condition, as highways for commerce, over which trade and travel are, or may be, conducted in the customary modes of trade or travel on water, and they constitute navigable waters of the United States within the meaning of the acts of Congress, in contradistinction from the navigable waters of the states, when they form in their ordinary condition, by themselves, or by uniting with other waters, a continued highway over which commerce is, or may be, carried on with other states or foreign countries in the customary modes in which such commerce is conducted by water."

Mr. Justice Davis states thus:

> "It would be a narrow rule to hold that in this country, unless a river was capable of being navigated by steam or sail vessels, it could not be treated as a public highway. The capability of use by the public for purposes of transportation and commerce affords the true criterion of the navigability of a river, rather than the extent and manner of that use. If it be capable, in its natural state, of being used for purposes of commerce, no matter in what mode the commerce may be conducted, it is navigable in fact, and becomes in law a public river or highway; vessels of any kind that can float upon the water, whether propelled by animal power, by the wind, or by the agency of steam, are, or may become, the mode by which a vast commerce can be conducted, and it would be a mischievous rule that would exclude either in determining the navigability of a river. It is not, however, as Chief Justice Shaw said (21, Pickering, 344): 'Every small creek in which a fishing skiff or gunning canoe can be made to float at high water which is deemed navigable, but, in order to give it the character of a navigable stream, it must be generally and commonly useful to some purpose of trade or agriculture.'"

The United States Government through the War Department has jurisdiction over all the navigable waters of the country, and has the right to dictate as to the character and location of all proposed bridges for crossing them, irrespective of whether permission to build them were obtained from Congress or State Legislature, consequently bridge engineers in general practice should acquaint themselves with the rules and regulations of the said Department in regard to bridging such waters.

[illegible] regulations are [illegible] of the War Department, [illegible] by Congress to establish general rules [illegible] and most of its tributaries, but it did [illegible] On March 23, 1906, Congress approved [illegible] of bridges over navigable waters." It [illegible]

"An Act to regulate the construction of bridges [illegible]

"*Be it enacted by the Senate and House of Representatives* [illegible] *America in Congress assembled*, That when, hereafter, authority [illegible] any persons to construct and maintain a bridge across [illegible] waters of the United States, such bridge shall not be built [illegible] plans and specifications for its construction, together with [illegible] construction and such map of the proposed location as may be [illegible] standing of the subject, have been submitted to the Secretary [illegible] Engineers for their approval, nor until they shall have approved [illegible] fications and the location of such bridge and accessory works; and when [illegible] any bridge to be constructed under the provisions of this Act have been [illegible] Chief of Engineers and by the Secretary of War it shall not be lawful [illegible] such plans, either before or after completion of the structure, unless [illegible] such plans has previously been submitted to and received the approval [illegible] of Engineers and of the Secretary of War.

"Sec. 2. That any bridge built in accordance with the provisions [illegible] be a lawful structure and shall be recognized and known as a post route, [illegible] higher charge shall be made for the transmission over the same of the [illegible] and the munitions of war of the United States than the rate per mile [illegible] portation over any railroad, street railway, or public highway leading to [illegible] and the United States shall have the right to construct, maintain, and [illegible] any charge therefor, telegraph and telephone lines across and upon [illegible] approaches; and equal privileges in the case of said bridge and its [illegible] be granted to all telegraph and telephone companies.

"Sec. 3. That all railroad companies desiring the use of any [illegible] in accordance with the provisions of this Act shall be entitled to equal [illegible] leges relative to the passage of railway trains or cars over the same [illegible] proaches thereto upon payment of a reasonable compensation for such [illegible] of any disagreement between the parties in regard to the terms of such [illegible] to be paid all matters at issue shall be determined by the Secretary of [illegible] the allegations and proofs submitted to him.

"Sec. 4. That no bridge erected or maintained under the provisions [illegible] shall at any time unreasonably obstruct the free navigation of the waters [illegible] is constructed, and if any bridge erected in accordance with the provisions [illegible] shall, in the opinion of the Secretary of War, at any time unreasonably [illegible] navigation, either on account of insufficient height, width of span, or [illegible] there be difficulty in passing the draw opening or the drawspan of such [illegible] steamboats, or other water craft, it shall be the duty of the Secretary [illegible] giving the parties interested reasonable opportunity to be heard, to notify [illegible] owning or controlling such bridge so to alter the same as to render navigation [illegible] or under it reasonably free, easy, and unobstructed, stating in such notice [illegible] required to be made, and prescribing in each case a reasonable time in [illegible] such changes, and if at the end of the time so specified the changes so [illegible] been made, the persons owning or controlling such bridge shall be [illegible] violation of this Act; and all such alterations shall be made and all [illegible] shall be removed at the expense of the persons owning or operating [illegible]

persons owning or operating any such bridge shall maintain, at their own expense, such lights and other signals thereon as the Secretary of Commerce and Labor shall prescribe. If the bridge shall be constructed with a draw, then the draw shall be opened promptly by the persons owning or operating such bridge upon reasonable signal for the passage of boats and other water craft. If tolls shall be charged for the transit over any bridge constructed under the provisions of this Act, of engines, cars, street cars, wagons, carriages, vehicles, animals, foot passengers, or other passengers, such tolls shall be reasonable and just, and the Secretary of War may, at any time, and from time to time, prescribe the reasonable rates of toll for such transit over such bridge, and the rates so prescribed shall be the legal rates and shall be the rates demanded and received for such transit.

"Sec. 5. That any persons who shall fail or refuse to comply with the lawful order of the Secretary of War or the Chief of Engineers, made in accordance with the provisions of this Act, shall be deemed guilty of a violation of this Act, and any persons who shall be guilty of a violation of this Act shall be deemed guilty of a misdemeanor and on conviction thereof shall be punished in any court of competent jurisdiction by a fine not exceeding five thousand dollars, and every month such persons shall remain in default shall be deemed a new offense and subject such persons to additional penalties therefor; and in addition to the penalties above described the Secretary of War and the Chief of Engineers may, upon refusal of the persons owning or controlling any such bridge and accessory works to comply with any lawful order issued by the Secretary of War or Chief of Engineers in regard thereto, cause the removal of such bridge and accessory works at the expense of the persons owning or controlling such bridge, and suit for such expense may be brought in the name of the United States against such persons, and recovery had for such expense in any court of competent jurisdiction; and the removal of any structures erected or maintained in violation of the provisions of this Act or the order or direction of the Secretary of War or Chief of Engineers made in pursuance thereof may be enforced by injunction, mandamus, or other summary process, upon application to the circuit court in the district in which such structure may, in whole or in part, exist, and proper proceedings to this end may be instituted under the direction of the Attorney-General of the United States at the request of the Secretary of War; and in case of any litigation arising from any obstruction or alleged obstruction to navigation created by the construction of any bridge under this Act, the cause or question arising may be tried before the circuit court of the United States in any district which any portion of such obstruction or bridge touches.

"Sec. 6. That whenever Congress shall hereafter by law authorize the construction of any bridge over or across any of the navigable waters of the United States, and no time for the commencement and completion of such bridge is named in said Act, the authority thereby granted shall cease and be null and void unless the actual construction of the bridge authorized in such Act be commenced within one year and completed within three years from the date of the passage of such Act.

"Sec. 7. That the word 'persons' as used in this Act shall be construed to import both the singular and the plural, as the case demands, and shall include municipalities, quasi-municipal corporations, corporations, companies, and associations.

"Sec. 8. That the right to alter, amend, or repeal this Act is hereby expressly reserved as to any and all bridges which may be built in accordance with the provisions of this Act, and the United States shall incur no liability for the alteration, amendment, or repeal thereof to the owner or owners or any other persons interested in any bridge which shall have been constructed in accordance with its provisions."

The preceding "Act" is very general in its nature, and is both interesting and useful to bridge engineers as far as it goes; but much more detailed information is necessary in order to prepare properly the plans

and other papers to submit to the Chief of the purpose of obtaining the formal approval of any proposed construction. Ordinarily it is not bridge plans thus approved, provided that the the following rules:

First. Generally the applicant must have gress or the legislature of one of the States a charter river at either a certain location or within certain limits. however, the law permits (under Section 9 of the River of March 3, 1899) the construction of bridges over further Congressional authority, if authorised by either State laws.

Second. The applicant must present with his person or by letter, the following papers:

a. A copy of, or reference to, the law authorising the the bridge. In case it be a special State law, the copy to by the secretary of the state, under seal.

If the law employed be a general one, a simple reference by volume, page, and section will be sufficient.

Where the legal authority to build a bridge is the charter or articles of incorporation of a company, a paper, *infra*, will suffice.

In cases where State laws vest the power to authorise tion of bridges in county officers, such as boards of courts, certified extracts from the proceedings of such be furnished.

b. Drawings, in triplicate, showing the plan of the bridge, and clear heights of spans, widths of draw openings, abutments, etc., and those features which affect navigation. construction are not required.)

c. A map, in triplicate, showing the location of the a distance of one mile above and one-half mile below the tion, such data in regard to low and high water, direction of currents, soundings, existing bridges, etc., as may be enable the Secretary of War to judge whether the location is

If the applicant is a corporation, in addition to the papers above there will be required the following:

d. A copy of the Charter or Articles of Incorporation of the certified to by the secretary of the state, or such other have the custody of the original, under seal.

e. A copy of the minutes of the organization of the fied to by the secretary thereof under seal.

f. An extract from the Company minutes showing the of the Company, certified to by the secretary thereof

g. A copy of the proceedings of the Board of

pany accepting the provisions of the Act of Congress or Act of State Legislature granting the right to build the bridge, certified to by the secretary of the Company under seal.

h. An application signed by the President of the Company and addressed to the Secretary of War, submitting map, design, and papers, as required by the rule established by the Secretary of War on July 21, 1886.

i. A letter, in duplicate, addressed to the Secretary of War, signed by the President of the Company, authorizing the applicant to present the papers and plans in person and to do what may be necessary to obtain the approval of the said plans by the Secretary of War.

In the case of a well known corporation, the presentation of the papers enumerated under the headings *d*, *e*, and *f* may be waived.

The following extract from a general letter dated June 7, 1913, from the then Chief of Engineers, Gen. Wm. H. Bixby, addressed to the "District Officers of the Corps of Engineers," and entitled "Memorandum of Instructions for Use in Preparing Drawings to Accompany Requests for Secretary of War Permits," will supplement the preceding suggestions. Referring specially to bridges General Bixby says·

"A. In plan, or in horizontal section, the essential features are the outside lines of the structure which separate the area left for use of boats from the area occupied by the bridge.

"B. In elevation or in vertical section, the essential features are similar lines indicating clear heights under lowest points above high water, low water, and ordinary boating water, and clear widths between piers and fenders, etc., at same stages; and the outer boundary of the fixed parts of the bridge, and of its draw or movable parts.

"C. In both plan and elevation the essential features of the draw should be shown in the two positions of the draw, closed and fully open; but the unessential features of the draw and bridge ends (i. e., form of bracing, or trussing, and of bolting, other constructional details, material) are not needed to be indicated and their omission is generally preferable.

"D. Care should be taken to see that the points of the compass and the direction and relative strength of currents (both ebb and flow) are given close to the bridge and at both ends of the portion of the river shown.

"E. The extent of map should fulfill the conditions already required by the War Department circulars.

"F. The drawing showing general plan should contain a small inset map to show the connection of permit maps with some existing lake or coast survey map of the locality (to be briefly described by its number and title)."

Although under ordinary conditions there is no difficulty experienced in obtaining the approval of the War Department to the plan and location of a proposed bridge, there are times when the applicant will encounter many obstacles; and occasionally these will prove to be insurmountable. For instance, when two rival companies are trying to bridge a river at or near the same location, or when the navigation interests deem that the bridge would be an obstruction to river traffic, or when the Government engineers consider that the structure would interfere with the rectification of the stream or with probable future navigation, or

[illegible] continually employed [illegible] opposition to a [illegible] of the War Department, if the [illegible] he names a date and place for a [illegible] given by advertisements in those of the [illegible] likely to reach all the parties interested [illegible] the district engineer officer usually [illegible] important cases three of the U. S. Army [illegible] the proceedings are quite similar to those of a [illegible] evidence is all in and duly considered, the Board [illegible] which is almost always final, as it would be [illegible] waste. Such hearings are usually characterized by [illegible] of all the proceedings. Every one interested is given [illegible] and the judges almost invariably render an impartial [illegible] decision upon the principle of the "greatest good for [illegible] ber." Even the defeated parties generally recognize [illegible] award; and very seldom is there any complaint heard [illegible] or unfairness. As the members of the U. S. Engineers [illegible] guardians of the country's navigation interests, one [illegible] they are liable to be prejudiced on the side of river [illegible] to the railroads; but when river men endeavor to [illegible] project by unwarranted allegations of injury to [illegible] soon made to understand that they will not be allowed [illegible] terial progress of the country because some proposed [illegible] not favor their personal aims.

The army engineers endeavor to make it as easy [illegible] applicant to get his plans approved; and when they are [illegible] necessity for haste, they will make their decision with [illegible] While they are particular about the correctness of the [illegible] map, they require but little data concerning the plans for [illegible] —simply a profile of the crossing showing the outlines of [illegible] skeleton of the trusses, and the corresponding plan giving [illegible] sions and location of piers and abutments. They are not [illegible] the strength of the superstructure nor with the specifications [illegible] the bridge is to be built; for they consider that the owner is [illegible] interested not to permit of any construction that is going to [illegible] over, if it should, the débris would soon be removed by the [illegible] at the owner's expense. In examining the plans, they [illegible] business to see that the location not only complies with the [illegible] spect to both the spacing and the position of piers and [illegible] also that the bridge, when completed, will not dam the [illegible] nor cause currents which would be prejudicial to [illegible] posed location is considered upon its own merits, and it [illegible]

proved, although complying with both the law and the custom of the Department, in case that any peculiar features necessitate other restrictions. The questions involved are treated from the broad standpoint of common sense, and the only red tape that the applicant is liable to encounter is the little piece used to tie up his approved plans with the official papers by which they are accompanied.

While it is not practicable for any one to determine in advance what layout of spans for any proposed crossing will meet with the approval of the War Department, it is generally known what the usual requirements are for each principal river. By the way, though, these very properly vary on the different stretches of the stream, being more severe near the mouth than in the vicinity of the head of navigation. On the Missouri River, as high up at least as Omaha, the minimum clear openings between piers are four hundred (400) feet for high bridges, and two hundred (200) feet for the swing spans, and three hundred (300) feet for the fixed spans of low bridges; and the clear headway above high water is from fifty-five (55) to fifty (50) feet for high bridges and ten (10) feet for low bridges. However, concessions are sometimes made in respect to the vertical clearance of low bridges; because all that really needs to be assured is that the bottom chords are high enough to avoid danger from injury by floating trees and logs.

As the width of river is rarely such that a certain number of spans of minimum length will exactly cover the stream, it is evident that in most cases there will arise the question of whether it is best to shorten or lengthen each span or to place a short span at one end of the bridge. The decision will generally be in favor of either the last-mentioned method or the equal lengthening of all the spans, as the Department is loth to break its established rules, and will not do so if it can be avoided.

When an engineer is retained upon a bridge project for the crossing of a navigable stream, of which he does not know the War Department's requirements for clear span and clear headway, the first step for him to take is to write the Chief of Engineers and request him to state, either officially or otherwise, as he may prefer, what in ordinary cases would be the said requirements. At the same time he should endeavor to learn what is the Department's interpretation of the term "High Water," because on some rivers the Government has established standard high water grade lines that are materially lower than the extreme high water elevations; and if such a standard can be used for the high water mentioned in the Company's charter, a material saving in both grades and money can often be effected. This is especially true in the case of projected low bridges to be built as close to the water as practicable.

The following quotations are extracted from a Government publication entitled "Laws for the Protection and Preservation of the Navigable Waters of the United States." Only those clauses which touch either directly or indirectly on bridgework have been chosen. As they

are taken from Acts passed at several different times, they involve a certain amount of repetition, which it is hoped the reader will pardon:

"That it shall not be lawful to construct or commence the construction of any bridge, dam, dike, or causeway over or in any port, roadstead, haven, harbor, canal, navigable river, or other navigable water of the United States until the consent of Congress to the building of such structures shall have been obtained and until the plans for the same shall have been submitted to and approved by the Chief of Engineers and by the Secretary of War: PROVIDED, That such structures may be built under authority of the legislature of a State across rivers and other waterways the navigable portions of which lie wholly within the limits of a single State, provided the location and plans thereof are submitted to and approved by the Chief of Engineers and by the Secretary of War before construction is commenced: AND PROVIDED FURTHER, That when plans for any bridge or other structure have been approved by the Chief of Engineers and by the Secretary of War, it shall not be lawful to deviate from such plans either before or after completion of the structure unless the modification of said plans has previously been submitted to and received the approval of the Chief of Engineers and of the Secretary of War.

"That the creation of any obstruction, not affirmatively authorized by Congress, to the navigable capacity of any of the waters of the United States is hereby prohibited; and it shall not be lawful to build or commence the building of any wharf, pier, dolphin, boom, weir, breakwater, bulkhead, jetty, or other structure in any port, roadstead, haven, harbor, canal, navigable river, or other water of the United States, outside established harbor lines, or where no harbor lines have been established, except on plans recommended by the Chief of Engineers and authorized by the Secretary of War; and it shall not be lawful to excavate or fill, or in any manner to alter or modify the course, location, condition, or capacity of, any port, roadstead, haven, harbor, canal, lake, harbor of refuge, or inclosure within the limits of any breakwater, or of the channel of any navigable water of the United States, unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War prior to beginning the same.

"That where it is made manifest to the Secretary of War that the establishment of harbor lines is essential to the preservation and protection of harbors he may, and is hereby, authorized to cause such lines to be established, beyond which no piers, wharves, bulkheads, or other works shall be extended or deposits made, except under such regulations as may be prescribed from time to time by him: PROVIDED, That whenever the Secretary of War grants to any person or persons permission to extend piers, wharves, bulkheads, or other works, or to make deposits in any tidal harbor or river of the United States beyond any harbor lines established under authority of the United States, he shall cause to be ascertained the amount of tide-water displaced by any such structure or by any such deposits, and he shall, if he deem it necessary, require the parties to whom the permission is given to make compensation for such displacement either by excavating in some part of the harbor, including tide-water channels betweeen high and low water mark, to such an extent as to create a basin for as much tide water as may be displaced by such structure or by such deposits, or in any other mode that may be satisfactory to him.

"That every person and every corporation that shall violate any of the provisions of sections nine, ten, and eleven of this Act, or any rule or regulation made by the Secretary of War in pursuance of the provisions of the said section eleven, shall be deemed guilty of a misdemeanor, and on conviction thereof shall be punished by a fine not exceeding twenty-five hundred dollars nor less than five hundred dollars, or by imprisonment (in the case of a natural person), not exceeding one year, or by both such punishments, in the discretion of the court. And further, the removal of any structures or parts of structures erected in violation of the provisions of the said sections may be enforced by the injunction of any circuit court exercising jurisdiction in any district in

which such structures may exist, and proper proceedings to this end may be instituted under the direction of the Attorney-General of the United States.

"That it shall not be lawful to throw, discharge, or deposit, or cause, suffer, or procure to be thrown, discharged, or deposited either from or out of any ship, barge, or other floating craft of any kind, or from the shore, wharf, manufacturing establishment, or mill of any kind, any refuse matter of any kind or description whatever other than that flowing from streets and sewers and passing therefrom in a liquid state, into any navigable water of the United States, or into any tributary of any navigable water from which the same shall float or be washed into such navigable water; and it shall not be lawful to deposit, or cause, suffer, or procure to be deposited material of any kind in any place on the bank of any navigable water, or on the bank of any tributary of any navigable water, where the same shall be liable to be washed into such navigable water, either by ordinary or high tides, or by storms or floods, or otherwise, whereby navigation shall or may be impeded or obstructed: PROVIDED, That nothing herein contained shall extend to, apply to, or prohibit the operations in connection with the improvement of navigable waters or construction of public works, considered necessary and proper by the United States officers supervising such improvement of public work: AND PROVIDED FURTHER, That the Secretary of War, whenever in the judgment of the Chief of Engineers anchorage and navigation will not be injured thereby, may permit the deposit of any material above mentioned in navigable waters, within limits to be defined and under conditions to be prescribed by him, provided application is made to him prior to depositing such material; and whenever any permit is so granted the conditions thereof shall be strictly complied with, and any violation thereof shall be unlawful.

"That whenever the Secretary of War shall have good reason to believe that any railroad or other bridge now constructed, or which may hereafter be constructed, over any of the navigable waterways of the United States is an unreasonable obstruction to the free navigation of such waters on account of insufficient height, width of span, or otherwise, or where there is difficulty in passing the draw opening or the draw span of such bridge by rafts, steamboats, or other water craft, it shall be the duty of the said Secretary, first giving the parties reasonable opportunity to be heard, to give notice to the persons or corporations owning or controlling such bridge so to alter the same as to render navigation through or under it reasonably free, easy, and unobstructed; and in giving such notice he shall specify the changes recommended by the Chief of Engineers that are required to be made, and shall prescribe in each case a reasonable time in which to make them. If at the end of such time the alteration has not been made, the Secretary of War shall forthwith notify the United States district attorney for the district in which such bridge is situated, to the end that the criminal proceedings hereinafter mentioned may be taken. If the persons, corporation, or association owning or controlling any railroad or other bridge shall, after receiving notice to that effect, as hereinbefore required, from the Secretary of War, and within the time prescribed by him willfully fail or refuse to remove the same or to comply with the lawful order of the Secretary of War in the premises, such persons, corporation, or association shall be deemed guilty of a misdemeanor, and on conviction thereof shall be punished by a fine not exceeding five thousand dollars, and every month such persons, corporation, or association shall remain in default in respect to the removal or alteration of such bridge shall be deemed a new offense, and subject the persons, corporation, or association so offending to the penalties above prescribed: PROVIDED, That in any case arising under the provisions of the section an appeal or writ of error may be taken from the district courts or from the existing circuit courts direct to the Supreme Court either by the United States or by the defendants.

"That it shall be the duty of all persons owning, operating, and tending the drawbridges now built, or which may hereafter be built across the navigable rivers and other waters of the United States, to open, or cause to be opened, the draws of such bridges under such rules and regulations as, in the opinion of the Secretary of War, the public

[illegible] provided in such regulations shall [illegible] violation thereof shall be punished by a fine [illegible] less than one thousand dollars, or by imprisonment [illegible] not exceeding one year, or by both such fine [illegible] of the court: PROVIDED, That the proper action [illegible] may be commenced before any commissioner [illegible], and such commissioner, judge, or court shall proceed [illegible] by law in case of crimes against the United States. [illegible], in the opinion of the Secretary of War, the public [illegible] rules and regulations to govern the opening of [illegible] and other water craft, and such rules and regulations [illegible] shall have the force of law, and any violation thereof [illegible] provided.

"That expenses incurred by the Engineer Department in [illegible] hearings, reports, service of notice, or other action [illegible] of plans or sites of bridges or other structures built or proposed [illegible] navigable waters, or to examinations into alleged violations of [illegible] and preservation of navigable waters, or to the establishment [illegible] shall be payable from any funds which may be available for the [illegible] tenance, operation, or care of the waterways or harbors affected, [illegible] available in sums judged by the Chief of Engineers to be [illegible] funds available for examinations, surveys, and contingencies of rivers [illegible]

The following extract from a Government document, [illegible] Department of Commerce and Labor and entitled "[illegible] the Light-House Establishment," bears upon the subject [illegible]

"That any person, firm, company, or corporation required by law [illegible] light or lights upon any bridge or abutments over or in any navigable [illegible] fail or refuse to maintain such light or lights, or to obey any of the [illegible] regulations relating to the same, shall be deemed guilty of a misdemeanor [illegible] ject to a fine not exceeding the sum of one hundred dollars for each [illegible] day during which such violation shall continue shall be considered as a [illegible]

It is not worth while to reproduce here all the Government [illegible] regulations for the lighting of bridges over navigable streams [illegible] officers of any company owning or operating such structures [illegible] respond with the War Department so as to ascertain just [illegible] quirements are in respect to each particular case, then adhere [illegible] to such requirements.

CHAPTER LI

HYDROGRAPHIC SURVEYS FOR THE BRIDGING OF NAVIGABLE WATERS

FROM the preceding chapter, it is seen that the War Department requires certain data submitted along with the application for a permit to bridge any navigable stream. To secure such data it is necessary to make a survey. While it is being made it is well to enlarge its scope so as to secure all the information required in determining the layout and the possible treatment of the river so as better to protect the structure.

The best site having been settled upon for the location of the bridge, it remains to supplement the preliminary survey with the information needed by the War Department in passing on the application. The first step is to run an accurate traverse line on each side of the river and as near the bank as possible, so that "cross shots" may be taken as a check on the accuracy of the work. These traverse lines should extend at least one mile above the bridge and a half mile below it, or further if it be necessary to locate bends that will affect the matter of shore protection. These two traverse lines should be accurately chained and their angles (preferably azimuths) carefully read, so that with the "cross shots" a control system will be established as a basis for the further work of getting topography and hydrography. The level should be run over the traverse lines, and an elevation should be established at each angle point for future use, these angle points thus becoming bench marks.

This system of control having been completed, it becomes an easy matter to start from any of the angle points and, by stadia, to secure the topography of the valley affected by floods, and to locate any improvements in the area under consideration. Also from these same angle points the positions of the different soundings can be readily located by stadia. This method requires only one transit and one transitman. It gives positive results which cannot be obtained by the method of trying to get the boat on range between two flag-poles. It has a further advantage over the double transit method in that the stadia method is definite for all points, whereas the double transit method becomes uncertain as the two lines of sight approach parallelism.

For the purpose of making soundings, a light pole graduated in feet and tenths is best for shallow streams and moderate velocities. For deeper rivers or stronger currents a lead line is employed; and a fine steel wire and heavy lead may be used for very swift current. The man making the soundings gives the signal to the transitman on shore as to when to observe position; and at the same time he notes the depth and

calls it to the assistant in the boat, who records the exact time and the depth. Care must be taken to ensure that the pole or lead line is vertical and that the lead is on the bottom. It is absolutely essential that all the watches of the party used in recording time agree precisely; for if not, serious trouble may be encountered in the plotting. The transitman on shore reads the azimuth and the stadia and notes the exact time, recording all three of these in his book, either personally or by calling them to an assistant. The vernier is left unclamped for rapid motion of the transit, which is preferably controlled with the left hand following the motion of the boat. The telescope should be clamped on the horizontal axis and manipulated by the gradienter screw with the right hand, the watch lying open on the plate of the instrument. With a little practice the motion of the boat can readily be followed and readings rapidly made. The transitman signals the boat when he is through making an observation. Where the shots are not too close together he can do his own recording; but, otherwise, he will require an assistant to keep the notes. On clear days half mile shots can be taken. The stadia board can be slipped into a socket in the boat, prepared for that purpose; and it can be steadied by one of the crew.

The plotting of these notes is a simple matter and can readily be done with a large paper protractor and paper scale. The soundings should be reduced to elevations so that contours can be drawn for the river bed as well as for the flood plain. All data pertaining to high and low water lines should be placed on the map.

It will be necessary to ascertain the direction and strength of the current. If a current meter is not available, floats can be used for the purpose. A piece of 4″ × 4″ timber about three feet long makes a good float. It can be loaded at one end with pieces of iron so that it will remain vertical in the water, weight enough being used to submerge the stick to within a few inches of the water's surface. By having a hole at the end, a small flag can be employed, thus insuring that the float will be readily seen by the observer on shore. The float can be dropped from the boat, the position of which is determined by the transitman in the manner previously described; and it can be picked up by another boat lower down stream, the signal being given at the same instant to note the position and the exact time. If two boats are not available, range poles can be used for the lower station, and a man located on shore in line with the poles so as to signal the transitman when the float crosses the line. It would be best to repeat this observation several times in order to obtain a reliable average. The boat can follow the float down and pick it up after it crosses the line. In case of a wide stream it would be best to measure the velocity along different longitudinal sections of the channel. It should be remembered that the velocity thus ascertained is surface velocity, and is less than the maximum and greater than the mean.

These various data should be incorporated into a neat hydrographic map and profile for presentation with the application. The map should show the banks of the stream, the location of the proposed bridge, the high and low water lines, the observed water lines, the different directions and velocities of the current, and the soundings giving the depths at the various points as actually recorded. The survey should be properly tied in to a section corner so that its location can be identified on any of the standard maps.

CHAPTER LII

ÆSTHETICS IN DESIGN

[illegible] the recession of pioneering conditions, [illegible] and the general acquisition of culture there [illegible] more insistent call for structures that please the eye; [illegible] engineering profession, in order to keep pace with the [illegible] upon it, will need to give more and more attention to the [illegible] [illegible] of its creations. To do this the engineer must have [illegible] of those underlying principles of the science of æsthetics [illegible] his work, and also a realization of whose eye he should [illegible]

The foundation of æsthetics is of the subjective order—[illegible] the impression made on the mind of the observer by the [illegible] By varying either one of these basic factors (*i. e.*, the mental [illegible] the impression or the external object causing it) the [illegible] changed. Witness the different conceptions of the beautiful [illegible] held by the various divisions of the human species during the [illegible] stages of their evolution. The condition of mental [illegible] much to do with the pleasing effect, or lack of it, produced by [illegible] Hence the science of æsthetics is of a relative order and [illegible] change with the developing mind. We cannot as yet regard [illegible] as absolute and immutable. Such a condition can be [illegible] when the underlying basic principle of artistic science is [illegible] psychology and expressed in terms thereof. That basic [illegible] account for and predict the changing standards and precepts [illegible] This point of view is valuable in approaching the subject of [illegible] sign and in selecting a standard of excellence by which to [illegible] deficiencies of engineering structures from the æsthetic [illegible] Artists and architects have formulated various tenets during [illegible] centuries defining their conceptions of the artistic. To these [illegible] neer must look for his first provisional standard for [illegible] bering their origin and the conditions attending it, as well as [illegible] limitations surrounding any such standard.

The best presentation that the author has ever seen of the [illegible] underlying artistic design as related to bridges is that of his [illegible] late Henry Van Brunt, Esq., who at the time of its writing was [illegible] edged by his professional brethren to be one of the foremost [illegible] ters of the science of architecture. Upon request Mr. Van [illegible] forth his ideas in a letter to the author, written specially for [illegible] in his *De Pontibus;* and as the truths stated therein are [illegible]

today as they were at the time they were written, the said letter is herewith reproduced.

"My Dear Mr. Waddell:

"After looking over a portion of your instructive treatise on bridges, I find it quite impossible to comply with your request to furnish you with practical suggestions from an architectural point of view as to grace and beauty of design in such structures. As these qualities must be developed from the structure itself, as they must be evolved from its inherent economical and practical conditions, and as they cannot be successfully applied to it as an afterthought, it would be unbecoming for any layman to attempt to show by what process this evolution is to be accomplished. The problem is not an easy one; it is not to be solved by theory, or by any accident of invention or ingenuity. At present, at least, it can only be treated on general lines. Indeed, there is no one living, I fear, who can suggest a specific and easily applied remedy for that disease of engineering which is expressed in the curious fact that the most perfect results of science, at least in the art of steel-bridge building as now understood and inculcated, do not recognize any theory of beauty in line or mass.

"It is the business of the architect to express structure and purpose with beauty. It is the business of the engineer, as I understand it, to make structures strong, durable, rigid, and economical; to apply pure science, excluding, as a matter of principle, any device of art which, for the sake of mere ornamentation, may add to his fabric a pound of unnecessary weight or a dollar of unnecessary cost.

"It cannot be denied that to whatever extent the exercise of this principle may have affected the practice of engineers, they have succeeded, especially as regards bridge-building, in developing a structure which is in every essential respect orderly, consistent, and progressive from a practical point of view. From year to year this development toward mechanical perfection has been plainly visible. The structure of ten years ago has been reasonably and properly superseded by another and better structure, indicating a process of growth without a shadow of caprice; in this process discovery and invention have had their proper influence, uninterrupted by any conservative prejudice or by any theory of design which does not rest directly on practical considerations. But, as I have already observed, this admirable and prolific progress has not carried with it a corresponding progress in grace and beauty of design. In fact, these qualities seem to appear in an inverse proportion to the development of the structural scheme toward the practical idea of strength, stability, and economy. Consequently the stronger, the more rigid, the more economical the structure, the more uncompromising and the more hopeless it seems to be in respect to beauty. The modern steel-girder or cantilever bridge, while, according to our present knowledge, it is perfectly adapted to its uses and functions, is in nearly every case an offense to the landscape in which it occurs. Its lines, since they have ceased to be structural curves, have become hard and ascetic mathematical expressions, and have not been brought into any sympathy whatever with the natural lines of the stream which it crosses, of the opposite banks which it connects, of the meadows, forests, and mountains among which it is placed. All sylvan effects of harmony are shocked by its discordant intrusion. The vast aqueducts of the Romans, the arched bridges of stone, the catenary curves of the modern suspension bridges with their high towers, and some forms of bridges constructed with bowstring girders, are more or less affiliated with the natural conditions, so that they give no shock, save frequently of pleasure at their expression of grace and fitness. But we are assured that these structural forms are obsolete or are becoming obsolete, and that the straight bridge-truss spanning from pier to pier, the cantilever overhanging the perilous abyss, the pivoted draw-span, all constructed with cold geometrical precision, with hard, unfeeling lines of tension and compression, have taken their place, to the great advantage of the railroads and the greater security of the public. It is in vain that the conscientious engineer occasionally attempts to compromise with grace by ornamenting

its intersections by rosettes or buttons of cast iron,
of triumph at the entrance to his bridge with a
scrolls of forged iron, and tables cast and gilded with
promise comes too late; the main essential lines cannot be
this sort; and as far as the eye can see, these lines, though
generally affront the sense of beauty.

"Now it seems to me important to note that the
intimate in infinite expressions of beauty, and that beauty is
principles of natural growth. The Great Creator never
inanimate, ugly in making it strong or swift or durable, or in
of nature. Grace is a part of the system of creation. Is it
secondary creation to make things unlovely in proportion to their
adaptation to the satisfaction of his practical needs? Is this
some quality which is wanting in our science?

"But, it may be said, if a steel-trussed bridge, economically and
according to our present light, offends our ideals of grace and beauty,
is not in the structure, but in the rigidity and immobility of the ideals
established by conditions long since outgrown in the progress of
of the English bridge-builders in iron in the early part of the century
ideas resulted in constructions which, though they may satisfy the
and combine more or less gracefully with the landscape, are
scientific. The principles of structure involved are incorrect, and
pense was incurred in forcing into the design features conventionally
which had nothing to do with the structure. and which in fact were a
concealing rather than illustrating it.

"The architect will not find it difficult to agree with his brother,
a mask of ornamental cast iron, covering the essential features of the
to force upon it an effect of grace, is illogical in the extreme. Indeed, a
master of architecture has laid down the axiom: 'A form which admits
tion, or which is mere caprice, cannot be beautiful; and in architecture,
form which is not inspired by the structure ought, therefore, to be rejected
scientious modern architect aims to shape his design according to this
tion, and he has been thereby enabled to produce occasional effects of
imposing on his composition a single idea which is not suggested either by
or by the use of the building. Even a factory, a gasometer, a railway shed,
need not challenge the architect in vain to produce effects of fitness not
tent with the requirements of art. Indeed, the engineer himself, with
of art, has, in the evolution of the roof-truss, the locomotive, and many
machines, succeeded in satisfying ideals of beauty in the very process of
powerful, compact, and economical of material and space. The modern
war-ship has already, in this early stage of its rapid development,
ideas of maritime beauty, speed, and strength which prevailed in the time of
the other great historical admirals, and which were celebrated in the songs
and Campbell, an entirely different ideal, hardly less imposing, though
poetic recognition. But the evolution of the steel-trussed bridge has
neither old ideals of beauty, nor has it made new ideals. Its essential lines
apparent disregard or contempt for grace of outline or elegance of detail.
seems to be inherent in the present approved structural system of
straight, open-trussed girders or cantilevers, resting on rigid vertical
or iron, without regard to any other considerations excepting those of
requires to be satisfied as well as the trained intelligence, and demands
proportion, but a certain decorative emphasis expressive of especial
primitive post and lintel structure of stone was as hopeless, apparently
derivative, the steel-trussed bridge, until the Greeks, with unerring

verted it by perfectly rational processes into that ideal expression of beauty which is known as the Doric order. This Doric order is a structure which depends less upon subsidiary decoration than upon proportion for its unparalleled success as a work of art. The Parthenon would still be lovely without the sculptures of its friezes, metopes, and pediments. Its columns, reduced to dimensions which encumber them with no useless brute mass of material, were so treated with entasis, capital, and fluting as to express exactly members in vertical compression; its lintels were so subdivided as to draw attention to, and to illustrate, all their functions in the structural scheme. They contained no features of caprice or fancy. Now the essential qualities of the steel-girder bridge differ from those of the post and lintel of the Greeks because, in the former, the structure of the lintels permits of a wider spacing of the posts, and the posts have assumed the dual function of piers for vertical support and of buttresses to withstand the horizontal pressures of the stream in which they are built; the lintels, in their turn, have lost their quality as compact, solid, homogeneous masses, have been resolved into distinct elements, and have become a complicated and highly artificial openwork contrivance of light steel members, which in their dimensions and articulations have been so combined in tension and compression as to produce a structure capable of sustaining without change of form not only its own weight between bearing points far apart, but that of moving trains, and of bearing without detriment vibrations and wind-pressures, and the expansion and contraction of its material by changes of temperature.

"These compound lintels or trusses are in themselves triumphs of mind over matter. At this moment they express a stage of evolution which has been in process for a century, and which doubtless will continue to develop in directions impossible to anticipate. They are structures not dedicated to the immortal gods, like the post and lintel of the Greek temples, the decorative character of which was largely inspired by religious emotions, but devised to meet secular and practical conditions of an exceedingly unpoetic and unimaginative character. The mind of the architect appreciates the fine economy of these sensitive and complicated organisms, but it also recognizes that they are still in active process of development; that they are on trial, and will not reach final results until they shall have assumed those conditions of grace and beauty which are essential to completion. It is evident enough that all the features of perfection in animals have been very gradually evolved, by survival of the fittest and by adaptation to use, from the awkward and monstrous shapes of the antediluvian period; that geological erosion and drift have clothed the naked rocks with beauty; and that the whole vegetable creation has been improved by art. Nature herself is not contented with inelastic dogmas. In like manner, the locomotive, the steam-engine, the modern war-ship, have all become objects of awful beauty, not because of the imposition of unnecessary features, but because of the natural and reasonable growth of their essential structure.

"If, therefore, the ugly character of the present steel-trussed bridge is in itself a proof of the immaturity of the science which has produced it, the remedy, of course, must reside in the perfecting of the science, and this process of perfecting will be quickened, if beauty is recognized in engineering as it is in architecture, as an aim and not as an accident of growth. The architect guides and hastens this progress towards the perfect type by fundamentally composing his structure with a view to an agreeable proportion of its parts; in detail he studies to emphasize the special and important points of his structure by a decorative treatment which shall indicate conventionally the character of the work accomplished at these points. It is true, perhaps, that the structural forms of materials with which the engineers have to work, especially in bridge-building, are hardly so elastic and manageable as those at the command of the architect even in his simplest and most severely practical problems; but it is none the less true that the training of the engineer leads him too often to an absolute disregard, if not contempt, for those refinements of proportion and outline, and for all those delicate adaptations and adjustments of detail, which, though perhaps separately slight, and apparently of small

[illegible] the French [illegible]
[illegible] of the modern steel [illegible]
[illegible] in the latter category. It is not [illegible]
[illegible], which is natural, but from training, [illegible]
[illegible] conditions in which the bridge-builders [illegible]
[illegible] differences in manner and method of design, [illegible]
[illegible] of expenditure; but these extravagances [illegible]
[illegible] beauty; because the cold and rarefied atmosphere [illegible]
[illegible] in which they are accustomed to labor, has gradually [illegible]
[illegible] which works for art and elegance in design. Beauty [illegible]
[illegible] proved by mathematics; but mathematics, when it has been [illegible]
[illegible] in the development of a problem of construction [illegible]
[illegible] results. Such results do not come by accident in any [illegible]
[illegible] and generous observance of natural laws. The [illegible]
[illegible] beginning does not give some recognition to grace, [illegible]
[illegible] parts of construction, must be misleading and one-sided, [illegible]
perfection. The recognition of these qualities, I am entirely [illegible]
necessarily imply any sacrifice of practical accuracy in design or of [illegible]
in workmanship, nor need it affect materially that fine economy [illegible]
perfection.

Very sincerely yours,

Henry Van [illegible]

From the foregoing letter we may gather by direct
implication the following precepts.

1. A structure must be in harmony with its
appear as an intrusion thereon.

2. Good general lines are first necessary as a basis,
scale or proportion of parts.

3. Mere ornamentation generally affronts the sense of
fitness.

4. Methods of nature always culminate in
Methods of nature also culminate in the survival of the
our conceptions of beauty have as a basis functional efficiency.

5. Owing to man's mental inertia, the rigidity and
ideals established by old conditions prevent proper
progress of science and of the needed modifications in

6. A form which admits of no explanation, or which is
cannot be beautiful. It must have and show some purpose in
relation.

7. Each part of any structure should be treated in such
its function therein shall be apparent and emphasized
importance of that function.

8. Such emphasis may be attained by decorative
conventionally the character of the work accomplished by

9. Different kinds of material used in structures call
treatment and varying æsthetic standards.

10. The present steel-trussed bridge is inherently ugly; but with the further perfecting of the science of bridge design, and a recognition of the fact that beauty is an aim and not an accident of growth, æsthetic forms will be evolved.

The underlying thought connecting these precepts is that the structure must be fitted for the work it is to do, that it should express the truth, and that imitations and falsities are vicious and outside the realm of rational æsthetics.

Let us proceed to consider more in detail the several precepts above formulated. To secure harmony between the structure and its environment means the merging of its general outlines with those of the landscape. In this connection, it should be remembered that the bridge will likely be seen from various angles, and that each view-point will cause its own individual impression. In case of conflicting impressions, it becomes a matter of good judgment as to which should control. The merging of outlines can usually be secured by attention to the approaches, by extending the hand-rails beyond the structure proper, or by curving the wing-walls of the abutments. A small arch or girder span can often be given dignity by lengthening the approach walls or hand-rails. An illustration of this is the Wabash Railroad Bridge over the main drive entrance to Forest Park, St. Louis, Mo., shown in *Engineering News*, Vol. LII, page 431. An example of the disregard of this principle is the arch at Multnomah Falls on the Columbian Highway, Oregon, in which an extension of the hand-rail on the right bank would have tied the structure into the ground and prevented the unpleasant feeling of abruptness that must inevitably strike the observer. This defect could readily be overcome by planting shrubbery in a mass at the end of the present hand-rail, thus permitting the structure to merge into the landscape.

The achievement of good general lines is best attained by a study of the profile of the structure.

There is no feature of a bridge so pleasing to the eyes of all observers, cultivated and ignorant alike, as perfect symmetry in the layout of spans; consequently it should be attained whenever practicable, even if some extra expense be involved thereby. Unfortunately, the conditions are not always favorable to perfect symmetry of design; for the bed-rock will often dip rapidly, and thus necessitate the use of spans of different lengths, and the channel of the river often refuses to keep at midstream, persisting in hugging one shore. In such cases it becomes necessary to do the best one can with the unfavorable conditions, and to make the structure sightly, if not symmetrical. If there be a draw-span on one side of the river, it is best generally to make all of the fixed spans alike. Should each successive span—because of the gradual shelving off of the bed-rock, and for the sake of economy—be made longer as the bed-rock deepens, the result will be unsightly, even if the increment of span length be regular, for the reason that to an observer there is no apparent motive for thus

[illegible] the spans. Any divergence from which there is a self-evident reason produces upon the beholder, although it may be sufficient his admiration for the structure. If one can see at a glance of all the principal parts and peculiar features of of fitness will be satisfied and his general impression but the nearer the approach to perfect symmetry and the outlines, the more thorough will be his appreciation effect of the structure.

The outline of a bridge should not be monotonous; should changes in outline be too abrupt, unless there is son therefor, such, for instance, as a heavy intervening mass best effects are secured by outlines changing by easy form to another. An example illustrating abrupt changes lack of proper transition is that of the Chicago, Milwaukee Railway Company's bridge at Sixteen Mile Creek near tana, illustrated in Jacoby & Davis's book, "Foundations of Buildings," page 450. In case of simple truss spans, a chord giving the effect of a smooth curve adds much to the as well as to the economy. The harsh outlines of a cantilever generally be relieved by making the chords simulate a cantilevers offend in this respect.

In proof of this statement are offered the layouts shown and 25s, representing two great Mississippi River bridges, Memphis and that at Thebes. These constructions are In respect to the latter structure the author made a on the basis of using simple spans of the same length as those tilever bridge. He found the former layout to be no and he is confident that it is much the more æsthetic, in spite that it did not win in the competition. It is illustrated in central span having a length of 672 feet and each of the length of 522 feet. The former is simply a proportional the others. It might have improved the appearance to make span 472 feet long and each span adjacent thereto 572 feet, to obtain a gradual increase of importance in spans from the structure to the middle, as shown in Fig. 52*d*, but the conditions did not permit. Moreover, the change would slightly the total weight of metal, and the pound price would augmented a little because of the reduction in the amount of In the last figure it will be noticed that the proportional cess adopted for the submitted design has been carried into the minor spans, and that the effect thereof is pleasing.

As further evidence that it is possible to make æsthetic, there is shown in Fig. 52*a* a photographic study proposed bridge across the entrance channel to the

Cuba. It is submitted that the outlines have a graceful appearance, and that the layout is quite economic, for the distance from centre to centre of main piers was fixed by local conditions, and it was found advisable to make the suspended span as long as practicable in order to provide a wide opening for the full clear headway. The leading dimensions of the proposed structure are as follows.

Main opening from centre to centre of piers	808 feet
Length of suspended span	400 feet
Length of each cantilever arm	204 feet
Length of each anchor arm	200 feet
Vertical clearance above water at mid-span	196 feet
Ditto at ends of suspended span	190 feet
Width of main roadway	42 feet
Width of each sidewalk	8 feet

Grades in each direction to middle of suspended span, 5 per cent.

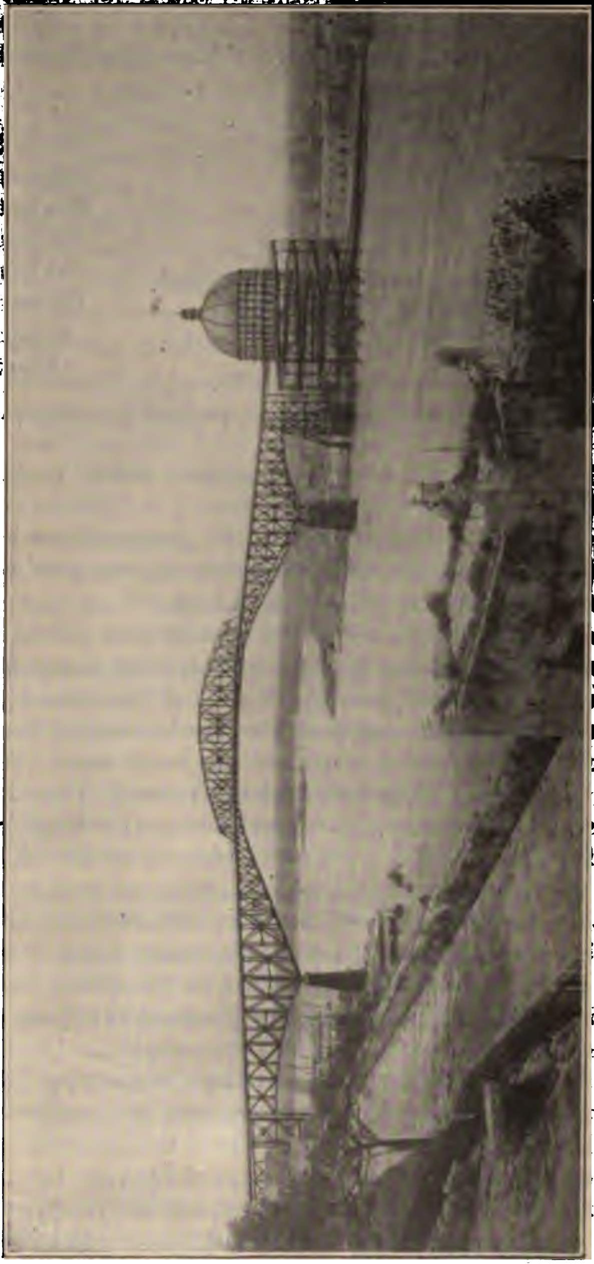
Attention is called to the spiral approach, which is described in Chapter XLV.

Attention is called also to a novelty in the picture shown in Fig. 52*a*, for it represents the structure as it will really appear after completion. The way this effect was obtained was as follows:

There was purchased from a Havana photographer a long panoramic photograph of the city, the harbor, and the adjacent vacant land on the left-hand side of the channel as one enters; and the camera position of the picture was marked on a plan of the location and of the bridge, a profile of the latter being also shown on the same sheet. A thorough study of the principles of panoramic perspective made it possible to construct the picture of the bridge and its approaches on the large photograph, which was afterward reduced. The result was so successful that many people have been deceived by it, thinking for a while that the photograph was taken from the finished structure. Of course, a careful examination of the picture will quickly show the incorrectness of such a first impression. In the preparation of this picture the author was aided by Señor Horacio Hevia, a young Cuban draftsman, to whose good taste and ability is due the satisfactory style of its finish.

This device can be used to great advantage in studying the æsthetics of any layout, for it enables one to determine how the completed structure will actually look.

The last design of the Quebec Bridge submitted by the commission of engineers is inferior in æsthetics to the design of the structure which failed, as the chords of the former are in straight lines which intersect each other abruptly. The ends of the structure also offend the eye by their abrupt termination. By making some slight changes in the outline it would have been practicable to improve greatly the appearance. Com-



the superior appearance of the latter. It is true that the [illegible] much shorter, being only one thousand feet long as [illegible]

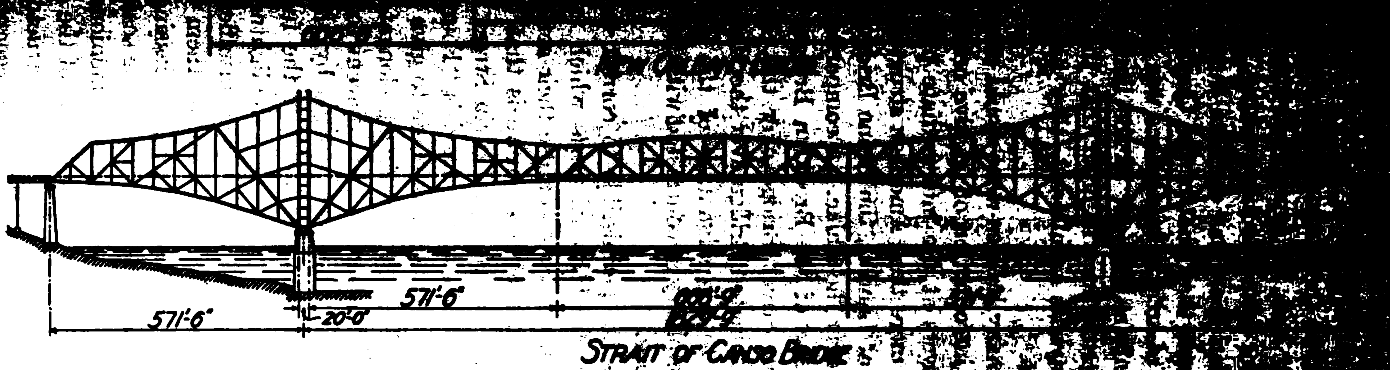


Fig. 52*b*. Contrasted Layouts of the Quebec Bridge, of the Proposed Bridge over the [illegible] and of the Proposed Bridge over the Strait of Canso in Nova Scotia.

hundred feet in the Quebec Bridge, accord[illegible] seriously against the legitimate drawing of a [illegible] of the two structures.

In 1904 the author made a study, with [illegible] mates of cost, for a proposed single-track, [illegible] signed for future double-tracking, across the [illegible] The main span was eighteen hundred and thirty [illegible] feet longer than that of the Quebec Bridge. In th[illegible] feature of artistic appearance was given full consid[illegible] was made as æsthetic as the limitations of his pers[illegible] taste permitted. In order that the reader may comp[illegible] three layouts mentioned, they are reproduced and [illegible] Fig. 52b.

In many bridges what would otherwise be a pleasing [illegible] by the introduction of massive ornamental portals at [illegible] sive towers at the intermediate piers. European bri[illegible] respect more than American structures. Examples of this are [illegible] Bridge at London, the Rhine Bridge at Mainz, and the [illegible] Bridge over the Rhine. A comparison of the general lines of th[illegible] with those of the Brooklyn Bridge, the Eads Bridge at St. [illegible] Chestnut Street Bridge over the Schuylkill River at [illegible] the Washington Bridge over the Harlem River in New York C[illegible] greatly to the advantage of the American designs, [illegible] their simplicity as contrasted with the over-ornamentation of th[illegible] structures.

It is not permissible to correct the hard, rigid outlines of a [illegible] the use of additional parts which falsely proclaim a different [illegible] for the members or confuse their action in the structure. An [illegible] of an offense of this nature is that of the New York Central [illegible] Belt Line Bridge over Colvin Street in Buffalo, N. Y., as illus[illegible] page 404 of Jacoby & Davis's "Foundations of Bridges and [illegible] There the attempt was made to give the plate girder spans so[illegible] an arch effect by introducing elongated curved brackets below the flanges of the girders and adjacent to the posts. The falsity of [illegible] struction is made conspicuous by the continuation of the lower angles in a straight line over the full length of the girder. [illegible] offense to the eye occurs in the lightness of the tapering columns [illegible] construction and their evident insufficiency to withstand the [illegible] such construction would put on them when the bridge is parti[illegible]

In addition to adopting a pleasing outline or profile for the [illegible] attention must also be paid to the scale or proportion of the par[illegible] is, the parts should bear a harmonious relation to each other [illegible] whole, and should appear to be of the same conception and [illegible] were details taken from other structures and illogically [illegible] In this connection it must be recognized that habit plays [illegible]

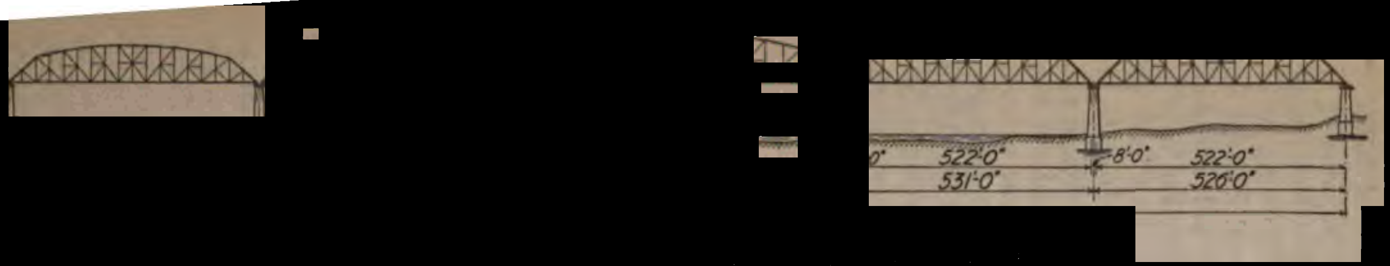


FIG. 52*d*. Alternative Layout for Proposed Bridge over the Mississippi River at Thebes, Ill.

[illegible] long usage we have [illegible]
[illegible] and pleasing, so that a departure [illegible]
[illegible] often confusing and disappointing. [illegible]
[illegible] and is acquired. When a new structural
[illegible] properties is introduced, a scientific
[illegible] our preconceived idea of scale and proper
[illegible] habituated to its rational utilisation and
[illegible] conception of harmonious proportions.
the question of whose eye the engineer should
the eye of the man looking backward to the old
eye of the man anticipating the approaching
attempting to adjust himself and his standards to the

Ornamentation can have no other justification
render clear or to emphasise the function of a member
Distinction must be made between appropriate and in
sary and unnecessary, and expensive and inexpensive
instance, while it is always proper to adapt the lines
the production of the most graceful effect, provided
sacrifice of constructive excellence be thereby involved
incurred, it would often be injudicious to expend money
tion. The builder probably cannot spare the money,
the structure may be such that any extra expense
would be absolutely wasted. If a bridge is to be located
be seen constantly by many people, it is well to spend
make it sightly, beautiful, and in keeping with its surroun
when it is to be placed in a dense forest or on a sandy
would seldom be seen, it would be folly to spend any more
struction than is called for by the engineering requirements
ditions, due allowance being made, of course, for a possible
the forest or desert in the not very distant future. Many
bridge designers have been guilty of violating this economic

Functional efficiency—the ability of any member or detail
the duty assigned it in an efficacious way—is a most valuab
If any part can be rendered more efficient by a modification
a change is to be made. It may mean that our æsthetic
require some readjustment, but the ultimate outcome will be
izing of that standard with the attainment of maximum
as an example the case of curved struts. There have been
of such, and even users thereof, in large and important
the mind trained in stress analysis this is a monstrosity
ated. As a better understanding and greater appreciation
ciples of mechanics come to the layman, a change in his
take place. This brings us once more to the question
engineer should attempt to satisfy.

[illegible] made up [illegible] the fact of a [illegible] capitals [illegible] with bad Gothic [illegible] better in itself without [illegible] than the *Galerie des* [illegible] scale, in which there is not [illegible] imposing in its effect that it deserves [illegible] engineering."

[illegible] thoroughly the Tower Bridge, [illegible] the eminent British architect; [illegible] his opinion, the structure has the [illegible] example of extravagance in bridge [illegible] small percentage of the entire [illegible] effective structure could readily [illegible] traveller travelling in England would [illegible] himself how far in that country [illegible] to what an extent the important [illegible] other European bridges fail in [illegible] appropriate ornamentation, such for in[illegible] bedecked with trimmings that outrage

[illegible] leads by antithesis to the next [illegible] superfluous members or parts, then, [illegible] are necessary should have that [illegible] such treatment as will fittingly [illegible] in the construction. Many struc[illegible] respect, especially those of masonry [illegible] reinforced concrete of late years has [illegible] arch spans, a type of structure that

admits of æsthetic treatment far more readily than do truss spans. Many arches fall short of their best effect just because sufficient attention has not been given to this principle of making evident the function and relative importance of each part of the structure. Their usual defects are as follows:

Failure to define the arch ring by letting it merge into the spandrel walls without any paneling for relief.

Failure to define the skew backs or springing lines of the arch.

Failure to separate the spandrel wall from the handrail by a belt course conforming with the grade of the roadway.

Failure to subordinate the handrail to the main part of the structure.

Failure to give the piers distinctiveness and the ignoring of the fact that the more important part of the pier is below the spring line.

The main portion of the improvement in architectural effect in American bridge engineering practice which has taken place in the last decade (and it is by no means inconsiderable) has come through the extensive building of reinforced-concrete structures. The following examples, selected mainly from the author's practice, will serve to illustrate some of the progress in bridge æsthetics that has been made by reason of this comparatively new material, which adapts itself so readily to the production of forms pleasing to the artistic sense of the beholder—at least, more strictly speaking, they will show what the author has been striving to do in order to improve the appearance of his structures.

Fig. 52*e* shows a photograph of the Colorado River Bridge at Austin, Texas. It is situated on the main street of the city leading to the State Capitol. On that account it was urgent that the structure be made as sightly as the limited amount of the appropriation would permit. The said amount was $200,000; and as the bridge is one thousand (1,000) feet long and fifty (50) feet wide from out to out, and as the pier foundations were somewhat expensive, on account of troubles incident to hard foundation material, it was a difficult matter to keep the cost within the appropriation. This was just barely accomplished; hence there was no money available for ornamentation. Perhaps this was just as well, for the simplicity of the design is probably its most pleasing attribute—at least this opinion has been expressed by a number of persons whose taste is indisputable.

Fig. 52*f* shows a photograph of the Arroyo Seco Bridge in the City of Pasadena, Cal. In this case also the appropriation was small—too small, in fact, for several reasons. Curiously enough, the limit was exactly the same as that of the Austin Bridge, viz., $200,000; and no persuasion of the author's was effective in having the amount increased. It was questionable whether a proper structure could be designed so that the entire cost, including the engineering, could be kept within the limit, and to settle the question the author sent to his office an outline

of the design, with exceedingly full data for estimating the cost, and had a complete detailed estimate prepared. It showed that the work could

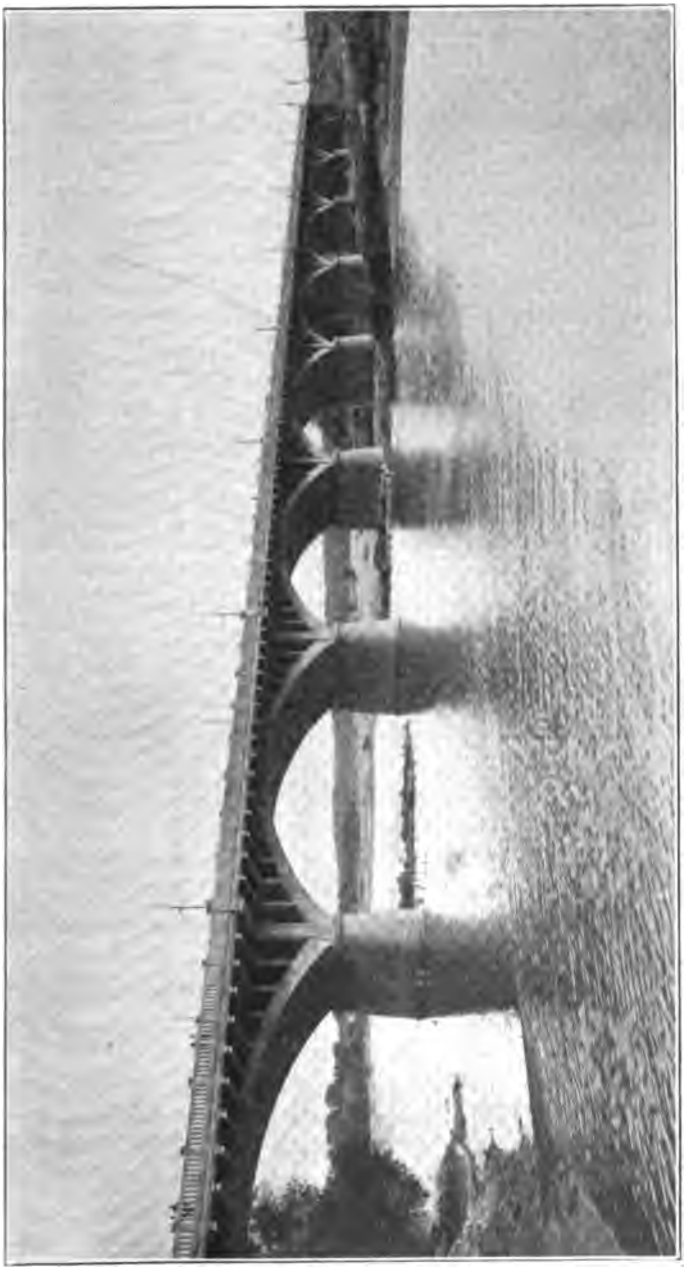


Fig. 52e. Colorado River Bridge at Austin, Texas.

be done with a possible margin of $2,500; and in consequence, the author's firm was retained to design the bridge and supervise its construc-

[illegible] reported as the estimated extra [illegible] but to no avail. As a last appeal [illegible] very well for you to state that [illegible] reason for building the structure as [illegible] but [illegible] telligent people view the bridge they [illegible] engineer did they have, what kind of a [illegible] what kind of a mayor did they have to permit [illegible] engineering principles as to build a structure on [illegible] have been shortened and, therefore, cheapened by [illegible] gent!'" To this the mayor replied: "I know it, but [illegible] We must build the cheaper structure." Unfortunately [illegible] for the peculiar layout is hidden from sight, as the [illegible] deepest part of the gorge are covered with débris.

The bridge was built by contract and just within [illegible] appropriation. Everyone is delighted with its appearance [illegible] to say, one of the principal features of the structure to [illegible] tants of the city point with pride is the graceful curve [illegible] However, the author was right when he made his [illegible] mayor, for on several occasions lately when visiting in [illegible] especially once when lecturing to the engineering students [illegible] University, he was asked by certain observing persons [illegible] *raison d'être* of the curve in plan. Notwithstanding [illegible] flaw in the structure, the conditions of the surrounding [illegible] favorable to the development of æsthetic construction [illegible] of the layout was so effectively made that residents and [illegible] are unanimous in their approval of the appearance of [illegible] From an engineering standpoint the author wishes to [illegible] record to the effect that while the entire bridge is designed [illegible] in strict conformity with the best engineering practice, [illegible] provided for are small and the spans were not figured for [illegible] tric railway traffic, and are not capable for doing so without [illegible] It is true that the city authorities desired to keep the car [illegible] the bridge for all time and to use it solely for pleasure driving [illegible] day will probably come when some ultilitarian administration [illegible] to run cars over the bridge, and they may even decide to [illegible] the fact that it was not designed to carry such heavy loading [illegible]

FIG. 52*f*. Arroyo Seco Bridge at Pasadena, Cal.

FIG. 52*g*. Twelfth Street Trafficway Viaduct at Kansas City, Mo.

Creek at Kansas City, Mo.

lines of the arch design were curved bottom chords of the function, certainly have a most

very artistic reinforced concrete located over Fall Creek on was designed by Robert C. Bar- of the eminent landscape engineer, the fine artistic effect of the

reinforced concrete arch bridge Kansas City, Missouri. It was Board, and has a most pleas-

Tunkhannock Creek Viaduct, built Railway Company at Nichol- portion of the line between Scran- this is the largest railroad viaduct description of it will be given, the

[illegible]

[illegible] ground, resting at the [illegible]
[illegible] between bed-rock and [illegible]
[illegible] ten 180-foot and two 100-foot full-
[illegible] arches. The main arches are [illegible]
each 14 feet wide and 6 feet apart; and the
[illegible] arch is surmounted by eleven 18' 6"
[illegible] carry two reinforced concrete parapet
[illegible] above the top of rail, for the protec-
[illegible] arches are also built in two ribs
[illegible] the main arches is continued to the
[illegible] approach fill covers the [illegible]
[illegible] superstructure, completely conce-
[illegible] not come upon the back of the last ma-
[illegible] thought was given to the [illegible]
[illegible] The 4' 3" centering ledge was covered
the centre was removed. Panels were also plac-
pilasters were used to relieve the otherwise pl-
were scored to hide the horizontal construction
spaced 4 feet apart. Each 4-foot lift contains
crete which was run in one operation.

The viaduct contains 167,000 cubic yards of con-
pounds of reinforcing steel. The volumes of the
vations for the piers were 40,000 and 3,500 cubic
Work on the viaduct started in August, 1912, and
for its completion.

Too much cannot well be said in praise of the
great structure. The immense size of the bridge, the
entire construction, the perfect symmetry of the layou-
larity of the numerous spans, the complete semi-circles
the harmonious effect of the superimposed detailing
to the æsthetic sense of the trained bridge engineer;
produced upon the mind of the layman cannot fail to

Among the author's most successful studies of æsth-
construction are the two New Zealand arches and the
of the C. N. P. R. R., described in Chapter XXVI and
in Figs. 26*k*, 26*i* and 26*j*. It is undeniable that the
artistic of all types of bridges, for its graceful lines are
It is to be hoped that as time passes American engineers
practice of adopting it for all crossings where it is suitable

The advent of new material with different physical

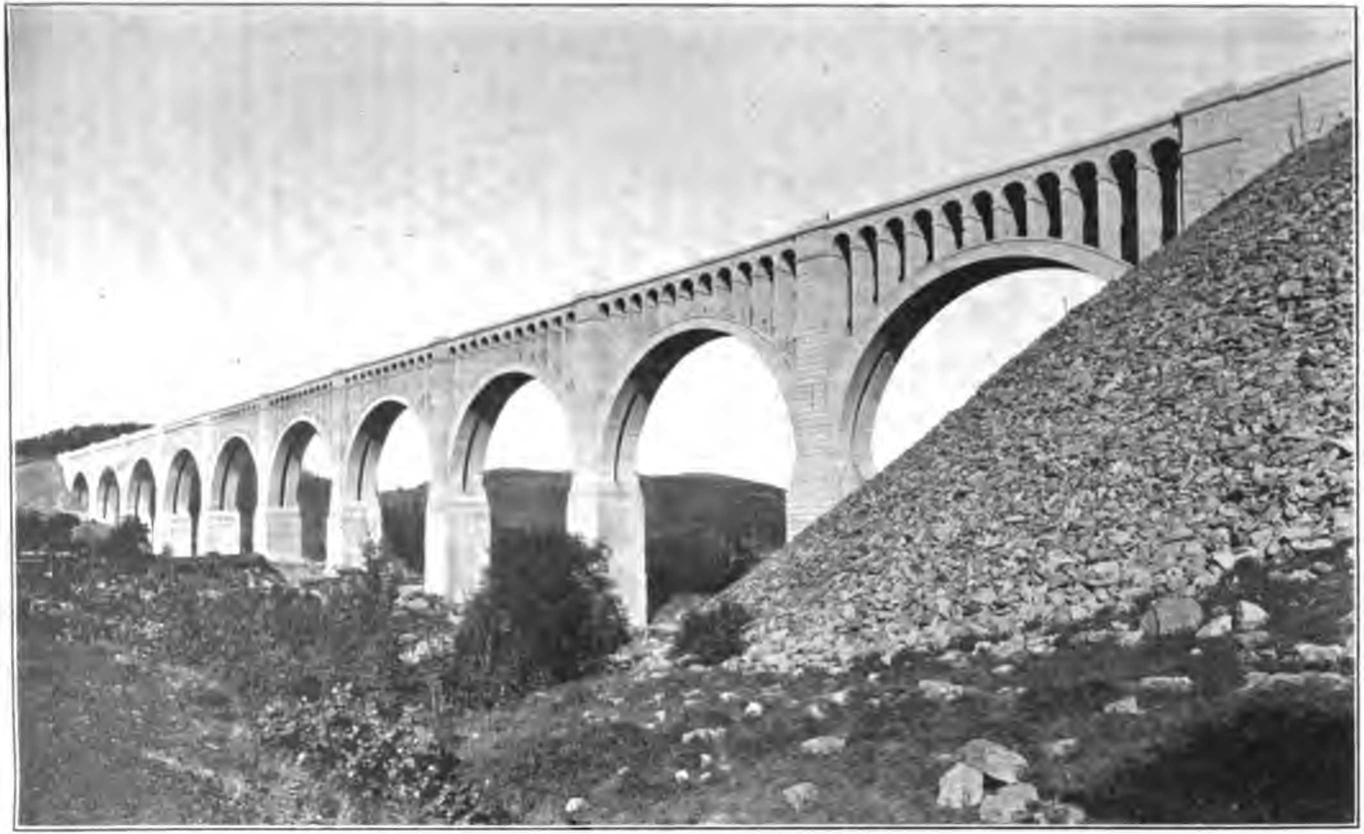


FIG. 52*j*. Tunkhannock Creek Viaduct on the Delaware, Lackawanna and Western Railway.

those customarily used places the designer in the need of a new standard of æsthetics. In developing such a standard, the fundamental criterion of fitness will be that of attaining the highest functional efficiency and employing it in the appearance of the entire construction. When this is attained, the old standards will gradually be made to conform to the new conditions.

In suggesting that "if a steel trussed bridge, economically and wisely constructed according to our present light, offends our ideals of grace and beauty, the fault perhaps is not in the structure, but in the rigidity and immobility of the ideals which have been established by conditions long since outgrown in the progress of science," Mr. Van Brunt has probably indicated the lines of convergence of engineering practice and architectural ideals; for while, as before stated, much can be done with most bridge designs to improve them without increasing their cost or affecting their efficiency, on the other hand, it is often impossible for an engineer to modify a bridge design so as to meet fully the critical objections of a good architect without introducing features both faulty and expensive. However, it must not be inferred from the foregoing that the author is defending the many bridge designers in their indifference to the artistic in construction. He believes that the preceding letter of Mr. Van Brunt's gives a very just and unprejudiced statement of the status of affairs at the time of its writing. But of later years more attention has been given to æsthetics in bridge design; and the author feels that some progress in artistic bridge construction has been made.

In 1897 the author wrote thus in *De Pontibus:*

> "The principal hindrance to the progress of æsthetic reform in bridge-building is liable to emanate from the bridge-manufacturing companies, who have been so accustomed to submitting competitive designs, and who have made in the past so much money thereby, that they will naturally consider any fundamental innovation of this kind as detrimental to their interests. Nevertheless, when some concerted action on the part of bridge specialists is inaugurated with the object of making bridge structures more sightly, it is probable that the manufacturing companies will be far-sighted enough to recognize that their true interests will not be subserved by offering any serious opposition to the proposed reform. Some obstruction is likely to come from managers of railroads, who have for years been used to buying their bridges as cheaply as possible without any regard to appearance, and too often with very little in respect to constructive excellence. It will devolve upon the chief engineers and the bridge engineers of railroads to influence the managements of their lines so as to incline them towards a more favorable consideration for appearance when deciding upon the designing and purchasing of their bridges.
>
> "But the moulders of public opinion in respect to the necessity for a due consideration of architectural effect in bridge-building must, of necessity, be the independent bridge engineers of the country, who are not so much influenced by monetary motives as are engineers connected with railways and bridge companies, although it must be confessed that some of the most prominent bridge specialists are the greatest offenders against the principles of æsthetics.
>
> "There is a general impression among engineers that to ingraft architectural effects upon bridge construction will always involve the necessity for an increased expenditure

of money; but this notion is incorrect, because there are many large and important bridges in the United States which could have been beautified, and at the same time cheapened, without in the slightest degree impairing their strength, rigidity, or efficiency, by simply modifying their harsh and uncompromising lines. It requires the expenditure of more thought than money to obtain an artistically designed bridge; for a little money will go a long way in producing a decorative effect upon such a structure.

"The author is a firm believer in the principle that true economy, engineering excellence of construction, and the best architectural effect will almost invariably be found to accompany each other, and be inseparable in the designing of any bridge. Moreover, any bridge built with due consideration for, first, efficiency, second, appearance, and, third, economy, will be satisfactory and gratifying to not only the trained expert, but also to the general engineer and railroad man, and even to the public; because when an observer notes that in such a structure all the engineering requirements are properly provided for, that there is no evident waste of material, and that all due advantage has been taken of the conditions to render the bridge sightly and in harmony with its surroundings, his eye will of necessity be pleased, and his inherent sense of fitness will cause him to regard the structure with a feeling of pleasure.

"To recognize and acknowledge the deficiencies of modern bridge designs from the artistic point of view is one thing, but to show how they are to be remedied is another; because, while it is easy to say that a certain structure does not come up to one's ideal of grace and beauty, it is very difficult to show exactly where the defects are, and what should or could be done to remove them."

Notwithstanding this, the author believes that the fundamental precepts previously enumerated, if followed consistently, will eliminate the most glaring sources of ugliness in bridge designs. To secure positive and satisfactory results in the decorative architectural details is more difficult, as that is a matter requiring special training; and, therefore, it cannot well be done through mere instinct.

In making a study of the æsthetics of a bridge design, after determining what spans are applicable, it is well to make one or more layouts on a large scale on the brown paper that is used in engineers' offices for pencil-drawings, indicating the circumscribing lines of all main members to scale, and tinting or filling between the said lines with pencil-shading; then tack the paper on a wall, and stand off at various distances to judge the effect. By doing this one can form a very correct opinion concerning the comparative merits of several layouts, and can ascertain where and how any particular layout can be improved. A consultation with several members of one's office force upon the architectural features of the various designs will often result in an improved effect; for nothing else will bring out both the favorable and the unfavorable characteristics of a plan like discussion. In the outlining of each span a great deal can be accomplished toward beautifying a structure, and there is no better way to study the general effect of any proposed outline than the one just indicated, viz., laying out various trusses to scale, tacking the paper to a wall, and criticising them. It will surprise any one who tries this method to see how quickly he can detect the slightest variation from correctness in outline, and what a difference in effect even a small change

[illegible] involved in the [illegible] gave his unqualified [illegible] outlines. In this problem there were [illegible] the depths of truss at the two hips and [illegible] the number of panels was settled by [illegible]

Fig. 52*k*. Swing Spans of the Missouri River Bridge at East [illegible]

straightness and section of the top chords were necessitated [illegible] questions of efficiency. The depth at the outer hips was first [illegible] by the requirements for clearance, rigidity, and appearance [illegible] depths at the intermediate hips and tower were settled by [illegible] cussion from the artistic point of view, due attention being [illegible] engineering questions involved by the various inclinations of [illegible] and inclined inner posts. In Fig. 52*k* is reproduced a photo[illegible] long swing spans of that structure.

Fig. 52*l* shows an outline diagram of an alternative [illegible] movable span of the Pacific Highway Bridge at Portland, [illegible] is being engineered by the author's firm. In the bidding [illegible] between this span and a vertical lift the latter was adopted [illegible] of its superior economy and more satisfactory operation. [illegible] the swing span are good, although the author is of the [illegible] of the East Omaha swing are better.

By no stretch of the imagination can any bascule [illegible] a thing of beauty. On the contrary, most of them are [illegible] can be seen by examining the various illustrations [illegible]

The lack of symmetry in a single-leaf bascule militates greatly against its appearance, and no addition of tower entrance or filigree construction can help it. The intrusion of an immense mass of concrete into the scenery is far from being artistic, and in most cases the counterweight has to be above the level of the deck. There is a condition, though, where the bascule construction can be adopted without much, or perhaps any, detriment to the æsthetics; but even in that case it cannot be said to add to the appearance, its effect being neutral rather than either positive or negative. The condition is that of a fairly low, highway, deck structure where the required clear opening is comparatively small. By using a double-leaf bascule with the bottom chords arched, keeping the counterweight entirely below the deck, and making all the fixed spans arches of about the same span length and general appearance as in the bascule, a good effect can be produced. In Fig. 52*m* is a layout of this type, being a study submitted a few years ago by the author to the City Engineer of Vancouver, B. C., for a proposed bridge over False Creek at Thurlow street. The bridge has not yet been built, but some day there will be a structure at or near that location, for the regular development of the city will necessitate one.

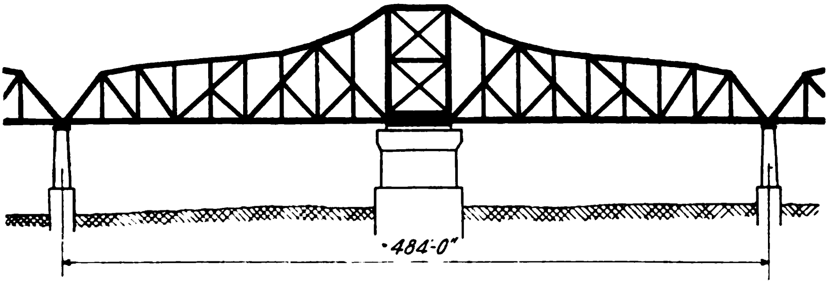


FIG. 52*l*. Layout of the Swing Span in the Alternative Design for the Pacific Highway Bridge over the Columbia River at Portland, Ore.

Nor is it an easy matter to fit a vertical lift span into a structure and obtain a fine architectural appearance; but the very magnitude and massiveness of the construction generally produce a pleasing effect upon the mind of the beholder, as do also the simplicity and the evident efficiency of the method of operation. A study of the illustrations in Chapter XXXI will convince one of the correctness of this assertion, and will prove to him that there is nothing inherently ugly in the vertical lift bridge as there is certainly in the bascule.

In determining the outlines of a span these few elementary principles are to be borne in mind:

First. There is nothing so ugly in a bridge as parallel chords unless it be a skew. However, for spans between one hundred and twenty-five feet and two hundred feet it is often best to use them, although in

certain cases where the loads are great [illegible] and top chords for spans considerably [illegible] just mentioned.

Second. While it is generally economical [illegible] long panels, no such extreme length should be [illegible] an awkward appearance due to flatness of diagonals [illegible]

Third. The curvature of the top chord should be [illegible] is consistent with a proper consideration of web [illegible] bracing.

Fourth. When it is practicable in Petit trusses to [illegible] chord to such an extent as to make too small the inclination [illegible] posts to the horizontal, it is permissible to let the [illegible] panel only and to make all the main diagonals extend [illegible] The effect is ungraceful, however, when the main diagonals [illegible] panel each near the ends of the span, and two panels each [illegible]

Fifth. When appearance alone is in question, trusses [illegible] mid-span are desirable; but an excessive truss depth is [illegible] reversion of bottom-chord stress by the wind load—a [illegible] has either to be avoided or provided for by stiffening the [illegible] In extremely heavy bridges, especially where the dead load [illegible] great, it is possible that an undue consideration for [illegible] might cause a designer to adopt a truss depth which would [illegible] too great for appearance, but this is not likely to occur very [illegible] of other limiting conditions.

Sixth. There are certain limiting relations between [illegible] depth of truss, and length of span which, for the sake of [illegible] ought not to be exceeded. Usually the rules established on [illegible] purely engineering questions will prevent these limits from [illegible] gressed, thus proving a maxim which the author has often [illegible] viz., that in any design any violation of engineering princip[illegible] a violation of good taste from an artistic point of view.

Seventh. A very graceful effect can be obtained by placing [illegible] horizontal struts of the overhead bracing in a cylindrical sur[illegible] to that which contains the panel points of the top chords, but [illegible] with different curvature.

In respect to the decoration of each span of a bridge, it may [illegible] that a little ornamentation is generally much better than a [illegible] and that this little should be appropriate and in keeping with [illegible] character of the structure. A prodigal use of cheap cast-iron [illegible] at a portal of a steel bridge is not in good taste, but it is perfe[illegible] to decorate the intersections of the members of the portal [illegible] plates or rosettes, to surmount the upper horizontal portal [illegible] æsthetically designed parapet, to use ornamental corner brack[illegible] the lower portal strut, to employ fancy name-plates [illegible] ranged, and to place ornamental figures of proper size and [illegible]

hips, pedestals, or middle of inclined end posts. It is also permissible to ornament the intermediate transverse vertical bracing to a slight degree by rosettes and knee-braces, but such decoration should be applied sparingly. Again, in large bridges it is proper to be somewhat extravagant in the use of metal at the portal for the sake of appearance, especially as such metal, if it does not add to the strength of the bridge, certainly increases its rigidity.

The ornamentation of viaducts and elevated railways is something which has never received in America any attention worth mentioning, as is proved by the inherent ugliness of nearly all the elevated roads of our great cities, and the painful plainness of our railway trestles throughout the country. It is principally this neglect of æsthetics in design which has created such bitter opposition on the part of the property owners to the building of elevated roads in the heart of the city of Chicago.

Electric lights and gas-fixtures of artistic pattern can be made great aids in securing a pleasing effect in designs for bridges and viaducts; and at night a well-studied distribution of incandescent lights can be made to produce a brilliant appearance at the portals of any large and important city bridge.

Ornamental handrails are also of great service in decorating trestles and bridges. While these handrails must appear as subordinate to the main body of the structure they can be emphasized by paneling or open work. The posts separating the panels should be subordinate to the end posts. In small spans, the handrail should be of the open type in order not to make the span appear too massive and top heavy. For large spans a solid handrail is desirable in order to give more body to the profile of the bridge. A handrail should not terminate abruptly without some apparent cause. A curving or flaring of the handrails at the approaches of the bridge adds to the æsthetic effect. If this cannot be accomplished then some ornamental post of dignified size, suitably decorated and surmounted by an artistic lamp post, will be found very effective.

Architectural effect in bridge building seldom derives much aid from paint, for the reason that it is generally best, on account of both convenience and good taste, to use but one color in painting a bridge. A proper choice of color, however, is a material advantage; and it is correct to vary the color in certain accessory portions of the structure, such as machinery-houses, the lettering on name-plates, etc. Some engineers have advocated painting the tension and the compression members of different colors, but this would get one into difficulties in spans where certain strictly tension-members are made stiff. Ornamental figures should be painted of the same color as the rest of the bridge. In general, it may be stated that for ordinary conditions of landscape the heavier the structure the lighter should be the color of the paint used, for the reason that if a bridge has an appearance inclining toward clumsiness this objectionable effect can be lessened by reducing the prominence

[illegible] look stronger by adopting a [illegible] members into greater relief [illegible] backgrounds, however, [illegible] paint even for slight structures, [illegible] definite outline.

[illegible] regard to the ornamentation of bridges by [illegible] artistic approaches, but little has yet been [illegible] being that any money so expended has [illegible] purpose, and consequently to the eye of the [illegible] to be entirely wasted. In Europe it is customary [illegible] and important bridges in this way; and the time [illegible] be the practice in America also.

Some twenty-one years ago the author had [illegible] thoroughly this question of the ornamentation of [illegible] ploying elaborate but strictly unnecessary approach [illegible] occasion was that of a world-wide competition for [illegible] to cross the Danube River at Buda-Pesth, Hungary, [illegible] tition he was unwise enough to enter. His plans were [illegible] withstanding the fact that they were probably the [illegible] within the set limits of costs of the structures or even [illegible] limits, on the plea that he had used higher unit stresses [illegible] in the specifications for the competition. Those unit [illegible] for spans of three or four hundred feet; and, as can be [illegible] and 52*o*, the author's spans were three times as long, [illegible] river from bank to bank in each case by a single span. [illegible] the impact method of computing live-load stresses had [illegible] vogue, it was customary in America to increase slightly [illegible] for working stresses for long-span bridges, and the author [illegible] followed that custom. The prize was awarded to a European [illegible] who, by the way, had violated one of the fundamental [illegible] the conditions by putting in estimates of cost nearly double [illegible] The reason for reproducing herein these layouts, which [illegible] pertain to ancient history, is to show the author's ideas as [illegible] gateways or entrances to large bridges should be like, as well [illegible] cate the fact that over two decades ago he had designed [illegible] longer than any that have yet been built or even seriously [illegible] These two designs, which are for spans of one thousand [illegible] eleven hundred feet, respectively, were worked out in [illegible] stress sheets and details for truss connections, pedestals, [illegible] lateral system, etc., being submitted, but also detailed plans [illegible] work and traveller, because the erection conditions were [illegible] obstruction to navagation of the middle portion of the [illegible] hibited at all times.

The shorter of the two spans, on account of its location, was required to be more elaborately ornamented than the other, hence in the former a steel construction having the effect of a dome surmounted with a tower was planned, while for the longer span a little castle at each of the four corners was deemed by the author to be sufficient. Much gray matter and, what was worse in those days, much good, solid cash were wasted on these plans and estimates, all going to prove the correctness of a statement made previously herein to the effect that it does not pay an engineer to compete on bridge plans without compensation, and unless the judges in the competition be truly bridge experts.

A proper proportioning of piers and abutments has a great deal to do with the obtaining of an artistically designed bridge; but, unfortunately, in these, even more than in the superstructure, the almighty dollar is generally the ruling influence in the design. In many bridges the piers do not seem to be massive enough for the spans; and, as is shown in Chapter XLIII, too often they are not sufficiently large to meet certain important engineering requirements, which are, as a rule, ignored by the average designer, and occasionally even by some who consider themselves bridge experts. In the author's opinion, if piers and abutments be adequately designed from an engineering point of view, they will not fall far short of the ideal of artistic excellence.

Believing that it will aid the reader in arriving at a better basis for his judgment to have pointed out the specific items or features of existing bridges worthy of commendation as well as those open to criticism, the author will avail himself of the excellent illustrations in Tyrrell's book on "Artistic Design of Bridges," to make further brief comment on bridges other than those previously mentioned. To avoid duplication of illustrations the reader is referred to that book.

Illustration No. 19 is that of an arch in Belle Isle Park, Detroit, Mich. The general effect is pleasing, but the solid handrail gives the structure a more massive appearance than it should have, considering the size of the opening. It is believed that an open-work handrail would have relieved this undue prominence of what should be a subordinate portion of the construction.

Illustration No. 20 is that of the proposed Hudson Memorial Bridge. While the ground profile prevented perfect symmetry, the general outlines of the structure are satisfactory.

Illustration No. 61 shows the outline of the Sukkur Bridge over the Indus River, India. It is totally lacking in every element of artistic design. The hard rigid profile, the derrick-like appearance of the cantilever arms, and the insignificance of the suspended span all offend the eye. Contrast this with the outline of the Beaver Bridge, No. 62, which even with its unsymmetrical layout caused by the end span has far more pleasing outlines. These two structures are also shown in Figs. 25*m* and 25*p* of this treatise.

Illustration No. 64 shows an effective adjustment of floor elevation.

Illustration No. 65 is that of the Niagara considered by itself, is quite effective; but the arch to the shallow approach spans, without an inter span, is not pleasing to the eye. A semi-arch been more effective.

Illustration No. 71 shows capriciousness and lacks in

Illustration No. 163 shows the effect of too short The appearance of this structure would have been these walls had been lengthened and curved outwardly.

Illustration No. 164 presents another case of too short and also failure to merge with the landscape. Contrast illustrations with that of No. 165.

Illustration No. 167 is that of the Forest Hills entrance Park, Boston, Mass. Lack of symmetry is emphasized portal at the high end.

Illustration No. 168 shows the effect of small spans piers. The importance of the latter is minimized by the spandrel walls and solid handrail, which gives a top-heavy to the structure. A better effect would have been secured the number of spans, lowering the springing line, and of the piers.

Illustration No. 170 shows the effect of too long a span, arch ring to appear as if springing from the ground slope abutments. This obscuring of the skew-backs hides their leaves the eye unsatisfied.

Illustration No. 175 is of the bridge at Hyde Park, N. Y., In general outline this is a very satisfactory structure. However, ring is merged into the spandrel walls and its function is

Illustration No. 183 presents an example of intrusion scape. The abutments project out into the stream, breaks in the shore lines. The suspension cables are not defined, giving on this account an appearance of weakness.

Illustration No. 199 is that of the Rocky River Bridge Ohio. The pleasing effect of this structure is marred by the ters at the shore piers; for they have no apparent object other porting small balconies, or bartizans, at the floor level. obscure the piers proper. The belt course at the springing have been carried entirely around the pier, and above this the pilaster with diminished section should have extended to cony. Compare this pier with that of the Washington Bridge Harlem River, illustrated in "Modern Framed Structures." the skew-backs are well defined, the portion of pier below sive (as it should be since it takes up the thrusts of the

portion above is subordinated by the smaller section, thereby bringing out its relative importance.

Illustration No. 205 is that of a highway bridge of reinforced concrete. This material is marked off to represent cut-stone masonry, which is in bad taste because it is deceptive; while the handrails or parapets are of rough rubble composed of boulders, giving the effect of strength and massiveness in the wrong place, in other words, overemphasizing the handrail.

Illustration No. 231 is that of the Kornhaus Bridge over the Aar at Berne, Switzerland. The main arch has a span of 384 feet and is terminated by handsome masonry piers, from which the smaller arches of the approach spans spring. Contrast the effect of this with that of the Niagara arch, shown in Illustration No. 65.

A critical study and comparison of these numerous illustrations in connection with the principles previously formulated in this chapter will assist the reader in cultivating his artistic perceptions and in the attainment of æsthetic results in his designing.

In concluding this chapter the author would advise his readers to read the whole of Tyrrell's book on "Artistic Design of Bridges," to consult the series of illustrations of European bridges in Vols. 43, 44, and 45 of the *Engineering Record,* and to study carefully Chapter XXVI on "The Æsthetic Design of Bridges," by David A. Molitor, Esq., C.E., in the "Theory and Practice of Modern Framed Structures." Although most of Mr. Molitor's illustrations are necessarily drawn from European structures, there are many features thereof which it would be well for American bridge-designers to adopt; notwithstanding the facts that European practice and American practice in bridge-building are fundamentally and essentially different, and that American engineers have little or nothing to learn from their brethren across the seas concerning the science of bridge design. From an artistic point of view, however, it must be confessed that the average American bridge is inferior to the average European structure; hence while it is advisable that American bridge-designers study carefully European practice in respect to æsthetics, they should be cautious to avoid thoughtless imitation; because decorative features which are appropriate to the heavy, massive, and costly bridges of Europe would be out of place when engrafted on some of the light, airy, and economic structures that may still be considered as characteristic of American bridge engineering, although the tendency nowadays in this country is toward heavier construction.

CHAPTER LIII

TRUE ECONOMY IN DESIGN

THE great majority of bridge designers believe that the most economic structure is the one for which the first cost is a minimum; and from the contractor's prejudiced point of view this is correct, because his interest generally lies in securing the contract for the work regardless of all other considerations than his own profits; but from the purchaser's point of view that structure is the most economic which will do the work required of it for as long a time as necessary with the least possible expenditure for operation, maintenance, and repairs, all these *desiderata* being obtained with the smallest practicable initial cost of construction.

In making an economic comparison of two or more designs for any proposed structure there are two methods of procedure, either of which is correct and satisfactory. The first is to find for each case what sum of money at the governing rate of interest will produce an income just sufficient to defray the average annual cost of operation, maintenance, repairs, and all other regular necessary expenditures, and add this amount to the total initial cost of the structure. The sum will be the "equivalent total first cost"; and if the designs be all satisfactory and the proposed structures of practically equal life, that structure for which the equivalent total first cost is the least is the most economic. The other method is to assume several future dates, preferably those at which certain large expenditures would probably have to be made for renewals or repairs of perishable portions, and compute the grand total cost to each date for each proposed structure under the assumption that it is then put into perfect condition, and allowing standard compound interest not only on the first cost but also on all annual expenditures. A comparison of these grand total costs at the several dates adopted will indicate clearly which is the most economic structure. A good example in the application of economics to bridges is given in Chapter LXX.

Treatise after treatise has been written upon the subject of economy in superstructure design, but unfortunately the result is simply a waste of good mental energy; for the writers thereof invariably attack the problem by means of complicated mathematical investigations, not recognizing the fact that the questions they endeavor to solve are altogether too intricate to be undertaken by mathematics. The object of each investigation appears to have been to establish an equation for the economic depth of truss, or that depth which corresponds to the minimum amount of metal required for the said truss; and, to start the investi-

gation, it seems to have been customary to make certain assumptions which are not even approximately correct. For instance, the principal assumption of several treatises in French and English is that the sectional area and the weight of each member of a truss are directly proportional to its greatest stress; or, in other words, that in proportioning all members of trusses a constant intensity of working stress is to be used, while in reality for modern steel bridges the intensities often vary considerably in the same specifications. Again, no distinction is made between tension and compression members, and no account is taken of the greatly varying amounts of their percentages of weights of details.

There is, however, one mathematical investigation concerning economic truss depths which is approximately correct, and which is based on assumptions that are very nearly true; but it holds good only for trusses with parallel chords. It is this:

Let A = weight of the chords,
B = weight of the web,
C = weight of the truss,
and D = depth of the truss.

Then
$$C = A + B. \qquad \text{[Eq. 1]}$$

But the weight of the chords varies inversely as the depth, or $A = \frac{a}{D}$, and the weight of the web varies directly as the depth, or $B = bD$, where a and b are constants; and, therefore, $C = \frac{a}{D} + b\,D$.

If C is to be made a minimum, we shall have, by differentiation,

$$\frac{d\,C}{d\,D} = -\frac{a}{D^2} + b = 0, \qquad \text{[Eq. 2]}$$

or
$$-\frac{A}{D} + \frac{B}{D} = 0, \text{ or } A = B. \qquad \text{[Eq. 3]}$$

As the second differential coefficient, after substitution according to the usual method for maxima and minima, comes out positive, the result obtained corresponds to a minimum. From this it is evident that, for trusses with parallel chords, the greatest economy of material will prevail when the weight of the chords is equal to the weight of the web. The author has verified this conclusion by checking the weights of chords and webs in a number of finished designs, finding it to be absolutely reliable. However, it is not of much practical value, because the economic depths of trusses with parallel chords are pretty well known; and, again, when spans are in excess of 175 or 200 feet, the chords of through-bridges are seldom made parallel. Moreover, the best depth to use is not often the one which gives the least weight of metal in the trusses.

It has been found by experience that, for trusses with polygonal top

chords, the economic depths, as far as
generally much greater than certain important
be used. For instance, especially in single-track
after a certain truss depth is exceeded, the overtu
pressure is so great as to reduce the dead-load tension on the
bottom chord to such an extent that the compression from the
carried by the lower lateral system causes reversion of stress,
reversion eye-bars are not adapted to withstand. A very deep
quires an expensive traveller, and decreasing the theoretically
depth increases the weight but slightly; hence it is really econo
reduce the depth of both truss and traveller. Again, the total
structure does not vary directly as the total weight of metal, for the
that an increase in the sectional area of a piece adds nothing to the
of its manufacture, and but little to the cost of erection; conse
it is only for raw material and freight that the expense is really
Hence it is generally best to use truss depths considerably less th
which would require the minimum amount of metal. For parall
the theoretically economic truss depths vary from one-fifth of
for spans of 100 feet to about one-sixth of the span for spans of
but for modern single-track-railway through-bridges the least allo
truss depth is about 30 feet, unless suspended floor-beams be used, a
which very properly has gone out of fashion.

In two five-hundred-foot spans of a combined railway and hi
bridge the author employed a truss depth of seventy-two feet; bu
was determined by the reversal of stress in bottom chords throu
pressure. A greater depth, if permissible, would have caused a
in total weight of metal. In another of his designs for a five-hu
and-sixty-foot span a truss depth of ninety feet was adopted, but
case the live load was very great, varying from ten thousand pou
lineal foot for short spans to eight thousand pounds per lineal fo
long ones; and the bridge is twenty per cent wider than in the
the two five-hundred-foot spans just mentioned. The greater the
load and the wider the bridge, the greater generally can the truss
be made advantageously.

The little mathematical investigation given in this chapter
applied with fair accuracy to plate-girder bridges and to the floor
of truss-bridges. If, for ordinary cases, in designing plate gir
will adopt such a depth as will make the total weight of the web
splice-plates and stiffening angles about equal to the weight of the
he will obtain an economically designed girder, and a deep and
For long spans, however, this arrangement would make the
deep as to become clumsy and expensive to handle; consequen
a span exceeds about forty feet, the amount of metal in the fla
be a little greater than that in the web; and the more the
forty feet the greater should be the relative amount of me

The true economic investigation for plate-girders is as follows, when the web is assumed to resist its share of the bending moment:

Let M = bending moment at mid-span,
h = depth of web,
t = thickness of web,
S = intensity of working stress for tension,
l = length of span,
and c = ratio of weight of details of web (*i. e.*, end stiffeners, intermediate stiffeners, splice plates, and fillers) to weight of the web plate itself.

The sum of the two flange areas at mid-span, including an allowance of fifteen per cent for rivet holes, will be given by the equation,

$$F = 1.15\left(\frac{2M}{hS} - \tfrac{1}{4}ht\right); \qquad \text{[Eq. 4]}$$

and the total weight of metal in the flanges, taking into account the fact that the cover plates do not run the full length of the girder, will be given approximately by the equation,

$$W_f = 3.4 \times 1.15\left(\frac{2M}{hS} - \tfrac{1}{4}ht\right) \times 0.8\,l,$$

$$= 3.4\,l\left(\frac{1.84\,M}{h\,S} - 0.23\,h\,t\right). \qquad \text{[Eq. 5]}$$

The weight of the web and its details will be

$$W_w = 3.4\,l\,(h\,t + c\,h\,t). \qquad \text{[Eq. 6]}$$

Therefore the total weight of girder will be

$$W_g = 3.4\,l\left(\frac{1.84\,M}{h\,S} - 0.23\,h\,t + h\,t + c\,h\,t\right),$$

$$= 3.4\,l\left(\frac{1.84\,M}{h\,S} + 0.77\,h\,t + c\,h\,t\right). \qquad \text{[Eq. 7]}$$

Differentiating with respect to h and placing the differential coefficient equal to zero gives

$$\frac{d\,W_g}{d\,h} = 3.4\,l\left(-\frac{1.84\,M}{h^2\,S} + 0.77\,t + c\,t\right) = 0. \qquad \text{[Eq. 8]}$$

Hence

$$\frac{1.84\,M}{h\,S} = 0.77\,h\,t + c\,h\,t; \qquad \text{[Eq. 9]}$$

from which we find

$$\frac{1.84\,M}{h\,S} - 0.23\,h\,t = 0.54\,h\,t + c\,h\,t, \qquad \text{[Eq. 10]}$$

and $$3.4\,l\left(\frac{1.84\,M}{h\,S} - 0.23\,h\,t\right) = 3.4\,l\,(0.54\,h\,t + c\,h\,t). \quad \text{[Eq. 11]}$$

But the value of c is generally about 0.3. Substituting this gives

$$3.4\,l\left(\frac{1.84\,M}{h\,S} - 0.23\,h\,t\right) = 3.4\,l\,(0.84\,h\,t). \quad \text{[Eq. 12]}$$

But the first member of this equation represents the weight of the flanges for the most economic condition, and the second member is eighty-four per cent of the total weight of the web plate without its details.

Dividing both sides of the last equation by 0.8 and cancelling the 3.4l gives

$$\left(\frac{2.3\,M}{h\,S} - 0.29\,h\,t\right) = 1.05\,h\,t, \quad \text{[Eq. 13]}$$

or $$1.15\left(\frac{2\,M}{h\,S} - 0.25\,h\,t\right) = 1.05\,h\,t. \quad \text{[Eq. 14]}$$

Evidently the first member of this equation represents the gross area of the flanges and the second member differs only a little from the gross area of the web and may without any great error be called such. Hence it may be stated that the theoretical maximum of economy exists when the gross areas of flanges and of web at mid-span are equal—a condition readily remembered. Although this is the theoretically correct criterion for economy, if it be applied to any particular case, it will generally be found that the resulting web depth is so excessive as to cause one or more of the following modifications in construction, as compared with the depth which would make the total weight of the flanges equal to the total weight of the web with all its details:

A. An additional splice or two in the web, or else a slightly increased pound price for the large plates.

B. Larger outstanding legs for all stiffening angles.

C. Reduction in the number of cover plates.

D. Narrowing of flange angles and necessitating thereby either an additional bracing frame or an increase in sectional area of the compression flange, in order to compensate for the greater ratio of unsupported length to width.

E. Possible thickening of web because of its greater depth.

F. Possible encroachment on under-clearance in deck spans, or raising of grade to avoid the same.

G. Possible difficulty in fabrication or shipment in case of long or heavy girders because of excessive depth.

Any one of these changes would be likely so to upset the economics of the case as to cause a material decrease in the theoretical depth found by the preceding investigation. One will not often make an error in economy by following the old established rule given in *De Pontibus* and reproduced herein previously to the effect that the best practicable arrangement is generally to make the weight of the flanges equal to the

weight of the web and its details; and there are occasionally cases where a saving of metal can be effected by making the web depth even smaller than that given by this old criterion, when by so doing a web splice may be avoided or smaller stiffening angles may be adopted. It should be borne in mind that there is quite a range in web depths over which the theoretic minimum weight is about constant, unless the thickness of the shallower web must be increased on account of the shear; hence one may often vary the dimensions of a plate-girder materially without affecting greatly the matter of economics. In Fig. 21*e* is given a diagram of economic depths of plate-girders with riveted end connections.

Concerning economic panel lengths, it is safe to make the following statement:—Within the limit set by good judgment and one's inherent sense of fitness, the longer the panel the greater the economy of material in the superstructure. Of course, when one goes to such an extent as to use a thirty-foot panel in an ordinary single-track-railway bridge he exceeds the limits referred to, because the lateral diagonals become too long, and their inclination to the chords becomes too flat for rigidity. Again, an extremely long panel might sometimes cause the truss diagonals to have an unsightly appearance because of their small inclination to the horizontal.

There is another mathematical investigation which is of practical value. It relates to the economic lengths of spans, and was first demonstrated in print by the author some twenty-five years ago in "Indian Engineering," although the principle was announced three years before then in the first edition of his "General Specifications for Highway Bridges of Iron and Steel." Strange to say, many engineers failed to see that there is any difference between this principle and an old practice of over fifty years' standing. The principle is that "for any crossing the greatest economy will be attained when the cost per lineal foot of the substructure is equal to the cost per lineal foot of the trusses and lateral systems." The old practice was to make for economy the cost of a pier equal to the cost of the span that it supports, or, more properly, equal to one-half of the cost of the two spans that it helps to support. Is not the difference between these two methods perfectly plain? In one the cost of the pier is made equal to the cost of the trusses and laterals, and in the other it is made equal to the cost of the trusses, laterals, and floor system. When one considers that the cost of the floor system is sometimes almost as great as one-half of the total cost of the superstructure, he will recognize how faulty the old method was. The following is the demonstration of the principle, simplified to the greatest practicable extent.

Let us assume a crossing of indefinite length, for which the depth of bed-rock is constant, and let

S = cost of the substructure per lineal foot of span,

T = cost per lineal foot of the trusses and laterals,

F = cost per lineal foot of the floor [illegible]

B = cost per lineal foot of the entire [illegible]

L = length of span.

$$B = S + T + F.$$

Now if we assume that slight changes in length [illegible] materially the sizes of the piers, the cost per foot of [illegible] inversely as the span length,

$$S = \frac{s}{L}.$$

Again, the cost per foot of the trusses and laterals, for [illegible] length of span, may be assumed to vary nearly directly [illegible] length; hence we may write the equation

$$T = t\,L.$$

The cost per foot of the floor system is practically independent [illegible] span length, being a function of the panel length, which does [illegible] materially with the span.

We now have the equation

$$B = \frac{s}{L} + t\,L + F,$$

in which B is to be made a minimum.

Differentiating and substituting, we have (as F is a constant)

$$\frac{d\,B}{d\,L} = -\frac{S}{L} + \frac{T}{L} = 0, \text{ or } S = T.$$

A further differentiation shows that the result corresponds to [illegible]

In reality the truss weight per foot increases more [illegible] span length. If r is the ratio of the span lengths, the truss [illegible] foot, for small changes in span lengths, will vary almost [illegible] ing to the ratio $r' = \frac{1}{2}(r + r^2)$. On the other hand, the [illegible] for the lateral system does not increase quite as rapidly [illegible] unless the perpendicular distance between central planes [illegible] increases. Unfortunately, though, the gain in truss weight [illegible] given by the assumed theory of variation is generally greater [illegible] corresponding loss for the weight of lateral system, [illegible] combined weights per foot of trusses and laterals generally [illegible] trifle faster than the span length. This is partially [illegible] that the pound price of metal erected and painted will [illegible] as the weight per foot increases. Again, there is often [illegible] in the assumption that the cost of the piers varies inversely [illegible] length, because the size of each pier may have to be [illegible] to accommodate the heavier spans; and this error is [illegible]

which rest on piles. If the perpendicular distance between central planes of trusses is increased because of the greater span length, the cost of each pier will be increased because of its greater length; but this will occur only occasionally. Ignoring the latter contingency, the two errors indicated, notwithstanding the fact that their effects are additive, are so small as not to affect materially the correctness of the results of this investigation concerning economic span lengths.

This demonstration proves that, in any layout of spans, with the conditions assumed, the greatest economy will be attained when the cost of the substructure per lineal foot of bridge is equal to the cost per lineal foot of the trusses and lateral systems. Of course, no such condition as a bridge of indefinite extent ever exists, nor is the bed-rock often level over the whole crossing; nevertheless the principle can be applied to each pier and the two spans that it helps to support by making the cost of the pier equal to one-half of the total cost of the trusses and laterals of the said two spans. Since working out this demonstration more than twenty-eight years ago, the author has made a practice of checking the correctness of the principle thereby established, by comparing the cost of substructure and superstructure in the principal bridges which he has designed and built, with the result that he finds it to be invariably correct.

The principle will apply also to trestles and elevated roads; for in the latter, when there is no longitudinal bracing, if we make the cost of the stringers or longitudinal girders of one span equal to the cost of the bent at one end of same, including its pedestals, we shall obtain the most economic layout. In an ordinary railroad trestle consisting of alternating spans and towers, it will be necessary for greatest economy to have the cost of all the girders in two spans (one span being over the tower) plus the cost of the longitudinal bracing of one tower equal to the cost of the two bents of said tower, including their pedestals.

The economics of reinforced concrete bridges have not received much attention from technical writers; and they are rather difficult to determine, as the quantities involved are influenced quite largely by the individual tastes of the designer. The problem is also complicated by the facts that the unit costs of the various portions of a structure may be more or less different, and that the unit costs of different types of construction may be decidedly unlike. In general, it may be said that the unit costs are lower for those structures which have the simplest form work; and a reduction will also be effected by decreasing the area of form surface per cubic yard of concrete. For instance, in the case of a wall or slab the form cost per cubic yard will vary practically inversely as the thickness of the said wall or slab. Evidently, therefore, it is desirable to concentrate the concrete into a few large members, rather than to employ a great number of small ones.

It should be noted that reinforcing bars less than ¾″ in diameter

command higher pound prices than do the larger bars. The extras for these small bars may be found in *Engineering News* the first of each month.

Taking up first girder bridges carried on columns, the following points must be considered:

First.—The panel length, when cross-girders are employed.
Second.—The number and spacing of the longitudinal girders.
Third.—The number of columns per bent.
Fourth.—The span length.
Fifth.—The use of reinforced concrete piles to carry the footings.

The panel length adopted is usually not of great importance from the standpoint of economy. Lengths of from eight to ten feet are generally employed; but a considerable variation from these values will cause little change in the combined cost of the slabs and cross-girders. A reduction in concrete quantities can frequently be effected by using long panels, and by carrying the slabs on short stringers supported by the floor-beams; but the extra form work required will generally overbalance this saving in volume.

The number and spacing of the longitudinal girders will depend upon the width and the height of the structure, the span length, and the load to be carried. For a high structure in which the economic span length is fairly long, it will nearly always be found best to employ two lines of girders, the spacing thereof being equal to about five-eighths of the total width of the structure; but for bridges much over sixty (60) feet wide the use of three or even four lines may be preferable. The slab in such structures is carried on cross-girders and cantilever-beams. For a low bridge in which the economic span length is short, it will generally be the cheapest to omit the cross-girders, except at the bents, and to employ several lines of longitudinal girders. The wider the structure, the more likely will this arrangement prove to be economical; and very heavy loads also favor its adoption. For a structure in which the span length is from one-half to two-thirds of the width, it will usually make little difference which of the two types is adopted, unless the height is rather large; and even in extreme cases the variation between the two is not likely to exceed ten per cent. Ordinarily, it will be found more desirable to use two lines of girders, with cross-girders and cantilevers about eight or ten feet centres.

The proper number of columns per bent depends on the number of longitudinal girders. When there are only two lines, two columns will, of course, be employed. When there are several lines of girders, there should generally be one column per girder in low structures, and two columns per bent in higher ones. In this latter case a heavy cross-girder will be required at each bent to carry the longitudinal girders.

The economic span length is affected by the height and the load, being

larger for greater heights and smaller for heavier loads. An approximate value thereof is given by the formula

$$l = h\left(0.3 + \frac{2000}{w + 1000}\right), \qquad \text{[Eq. 20]}$$

in which l = economic span length, centre to centre of supports,
w = load per lineal foot of girder (excluding its own weight),
and h = fixed height of structure.

The quantity h represents in any given case the height which is fixed, such as the height from grade to top of footing, height from grade to bottom of footing, height from underside of girder to top of footing, or height from underside of girder to bottom of footing, as the case may be. There is always a considerable range of lengths for which the quantities remain nearly constant. The formula gives values a trifle greater than those for which the quantities are a minimum, since the use of heavier sections will reduce slightly the unit costs of the concrete.

Reinforced concrete piles should be used under footings when a suitable foundation is to be found only at a considerable depth, or when a very large footing area would be required in order to reduce the pressures to a proper amount. A comparison must be made for each case as it arises, allowing properly for the cost of the column shaft, the footing, the piles, and the excavation. This latter item must not be overlooked.

The curves of Figs. 56*t* to 56*y*, inclusive, will be found of great value in studying the questions of economy of girder bridges, as most of the points involved can be settled directly thereby.

In arches the problem is much more complicated than in girder spans. The factors that affect the economic lengths are the cost of the arch ribs and that of the piers and abutments, the dividing lines between them being the verticals through the springing points. For any fixed span length the greater the rise, up to a limit of nearly one-half of the opening, the smaller will be the costs of both the arch and the piers or abutments which sustain it; but in most cases the distance from grade to ground is too small to permit the adoption of such a large rise; hence the problem generally resolves itself into a determination of the question, "How long can the span be made economically for a certain limit of rise?" This will be influenced by several important considerations, among which may be mentioned the following:

A. The live load used.

B. The amount of earth fill, if any, over the arches.

C. The depth of the foundations for the piers and abutments below the springing points.

D. The cost per cubic yard for putting the bases of piers and abutments down to a satisfactory foundation.

E. The necessity for a heavy or substantial appearance of the piers and abutments.

F. The height to which the large pier shafts must be carried.

G. The condition of the arch barrel—whether solid or ribbed.

H. The necessity, or otherwise, of adopting certain span lengths to meet existing conditions.

Here are too many variables for a theoretically correct economic investigation, hence the surest and most satisfactory way to proceed is to make by judgment the best possible layout consistent with the conditions, then two others, one involving a span length a certain number of feet greater and the other a span length the same number of feet less, and figure the costs of arches and piers (or abutments) for all three cases. Instead, though, of increasing and decreasing the span by a certain number of feet it may be necessary to reduce and augment the number of spans by unity. After the costs of the arches and piers or abutments are found and properly combined, the cost of these two portions of the construction per lineal foot of span for each of the three layouts can be computed and compared. The one which gives a minimum will indicate approximately the best span length to adopt.

In some cases it will prove to be economic to make the middle span of the bridge a certain length and reduce gradually the lengths of the spans at each side. If the configuration of the crossing will permit of a symmetrical layout on this basis, the effect will prove to be pleasing to the eye and generally economic of first cost, especially if a constant ratio of rise to span be maintained; because, as far as cost of substructure is concerned, the overturning moments from live load on a single span only and from inequality of dead load thrusts are kept low, owing to the fact that the lighter thrusts in the smaller span act with a greater lever arm than do the heavier thrusts of the longer span, on account of higher location of the points of springing. In adopting this expedient, though, care has to be exercised to prevent the principles of æsthetics from being violated.

The curves of Figs. 56*z* to 56*cc* will be found very useful in determining the economic span lengths of arch bridges.

There are many minor economic questions that arise in the designing and construction of bridges, among which may be mentioned the economic greatest lengths of different types of spans; the character of approaches to bridges; column spacing in bents supporting cross-girders with cantilever brackets; the economic functions of swing spans, cantilever bridges, arches, and steel trestles; the height of concrete retaining walls at which it is economic to begin to use reinforcing; the relative economics in employing medium steel, soft steel, standard steel, and alloy steel for bridge superstructures; the effect of erection on the economic layout of spans; the comparative economics of rim-bearing and centre-bearing swing spans; economy in choice of metal sections; and economy in shopwork. These various economic questions will now be taken up in the order enumerated.

Comparing rolled I-beam and plate-girder deck spans for modern

heavy live loads, the weights of metal are about equal for spans of fifteen feet; but the former are cheaper per pound than the latter by about four-tenths (0.4) of a cent, consequently the costs per lineal foot erected are equal for a span of about twenty feet.

Comparing deck plate-girders and through, riveted truss-spans, for which there is usually a difference of about one-half cent per pound erected in favor of the former, the weights of metal per lineal foot are the same for spans of one hundred and fifteen (115) feet, which is about the extreme limit of length for plate-girder spans shipped in one piece; hence it may be concluded that for all practicable lengths, deck plate-girder spans are more economic than through, riveted truss-spans. Besides, the use of such deck spans effects a great economy in the substructure by reducing the length of each pier from six to ten feet, the longer the span, of course, the less the reduction.

Comparing half-through, plate-girder spans and through, riveted truss-spans, for which there is a difference of about two-tenths (0.2) of a cent per pound erected in favor of the former, the weights of metal per lineal foot are the same for spans of seventy (70) feet, but the costs per foot are about equal for spans of seventy-five (75) feet. However, as plate-girder spans are in many respects more satisfactory than short, through riveted spans, the dividing point is generally placed at about one hundred (100) feet.

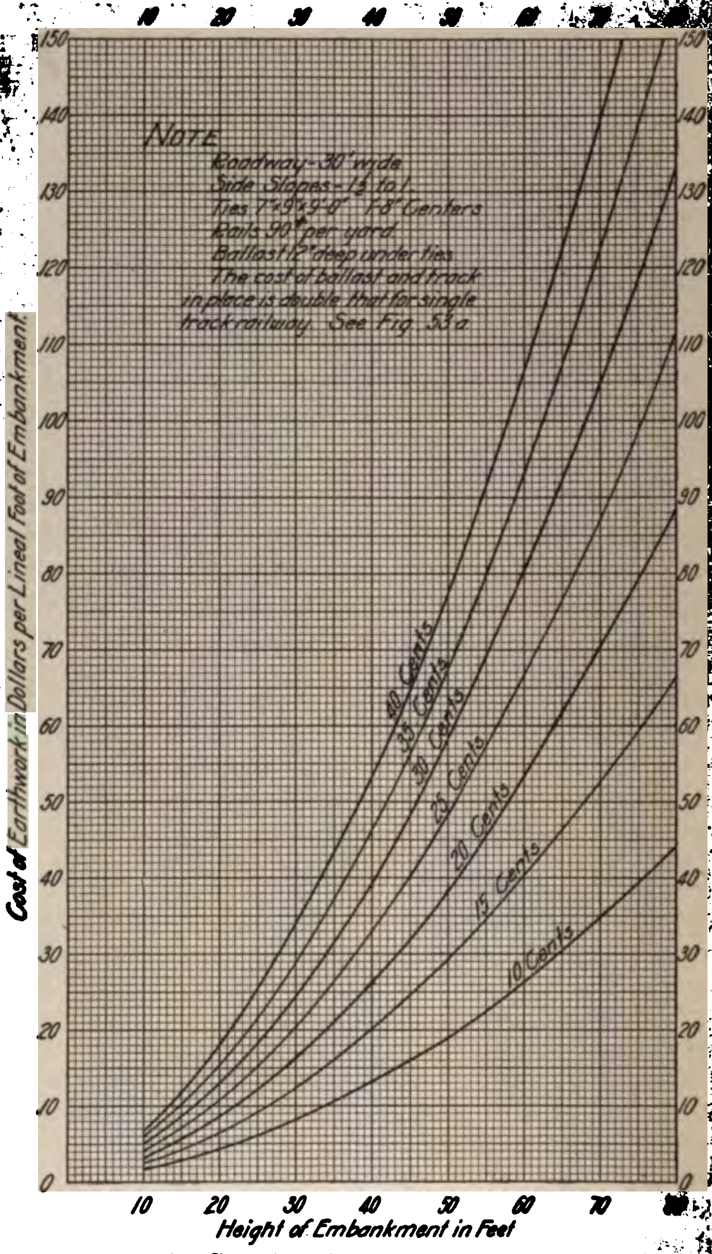
Comparing Pratt and Petit truss-spans, for which there is no difference worth mentioning in the pound prices of the metal, the weights per foot (and therefore the costs) are alike for single-track spans of three hundred (300) feet, and for double-track spans of three hundred and fifty (350) feet; but both constructive and æsthetic reasons necessitate limiting the lengths of Pratt trusses to about three hundred and twenty-five (325) feet.

The economics of approaches to bridges will involve the question of whether it is best and cheapest to build earth embankments, timber trestles, or steel viaducts, and at what heights it would pay to change from one kind to the other. Figs. 53*a* and 53*b* give the costs per foot of single-track and double-track earth embankments at various prices per cubic yard for earthwork; Figs. 53*c* and 53*d* give the costs per lineal foot of single-track and double-track timber trestles for various prices per M feet B. M. of timber in place; and from Figs. 55*nn* to 55*zz*, inclusive, and Figs. 56*k* to 56*m*, inclusive, can be computed the cost per lineal foot of steel viaducts. In estimating the cost of embankment, that of the retaining walls, abutments and culverts must be included. The cost of reinforced and plain concrete retaining walls can be determined from Figs. 56*r* and 56*s*, and that of plain concrete abutments can be taken directly from Fig. 53*e*. It must not be overlooked in this comparison that the quantities in Figs. 53*c* and 53*d* include the timber deck, which is not the case in the other diagrams. This economic study will involve

[illegible] maintenance, [illegible] beginning of this chapter. [illegible] of column spacing for bents when [illegible] is an interesting little problem, but the final [illegible] accordance with good judgment as well as [illegible] be too small, rigidity is likely to be sacrificed. [illegible] assumptions of approximate correctness the mathematical [illegible] problem is a possibility; but the equations involved [illegible] complicated that it is much better for any particular case [illegible] three spacings, compute the total weight of metal [illegible] each, and find the one which will give approximately the [illegible]. If the columns are placed at the quarter points of [illegible] dead load bending moment at the middle will be [illegible] and if the effect of stress reversion is ignored, the direct and [illegible] moments for the central portion of the beam will be [illegible] arrangement would be about the most economical possible. [illegible] reversion is considered, the sectional area of the middle [illegible] beam must be greater than that of the outside portions, hence [illegible] its length should be somewhat less than one-half of the [illegible] the columns would then be spaced somewhat closer than [illegible] located at the quarter points. The fact that the brackets [illegible] lighter near the outer ends than at the inner ones would, [illegible] to draw the columns together; but on the other hand [illegible] increase the weight of the splices and connecting details. [illegible] column spacing to adopt will depend upon the length of [illegible] for it is easily conceivable that the structure could be so [illegible] narrow that the quarter point spacing would be too close [illegible] resistance to wind pressure. Again, in such a case the wind [illegible] be so great as to necessitate an increase in column section [illegible] required to care for the live and dead load stresses only; [illegible] effect of wind pressure would enter the economic study. It [illegible] in most cases that it is inadvisable to space the columns [illegible] one-half of the total length of the beam.

The economic functions of swing spans are somewhat [illegible] mulate. The minimum perpendicular distance between [illegible] trusses for first-class construction should be the same as for [illegible] spans, viz., one-twentieth of the span length. It is evident, [illegible] that the narrower the bridge the less it will weigh and cost. [illegible] depths at ends of through swing bridges are generally [illegible] clearance requirements; but in long spans it is sometimes [illegible] the sake of vertical stiffness and to avoid the raising of [illegible] load on the other arm, to make the said depths still greater. [illegible] this increase is not of an uneconomic nature. For long [illegible] exceeding, say, four hundred (400) feet, the truss depth [illegible] should be about one-fourteenth ($^1/_{14}$) or one-fifteenth ($^1/_{15}$) [illegible]

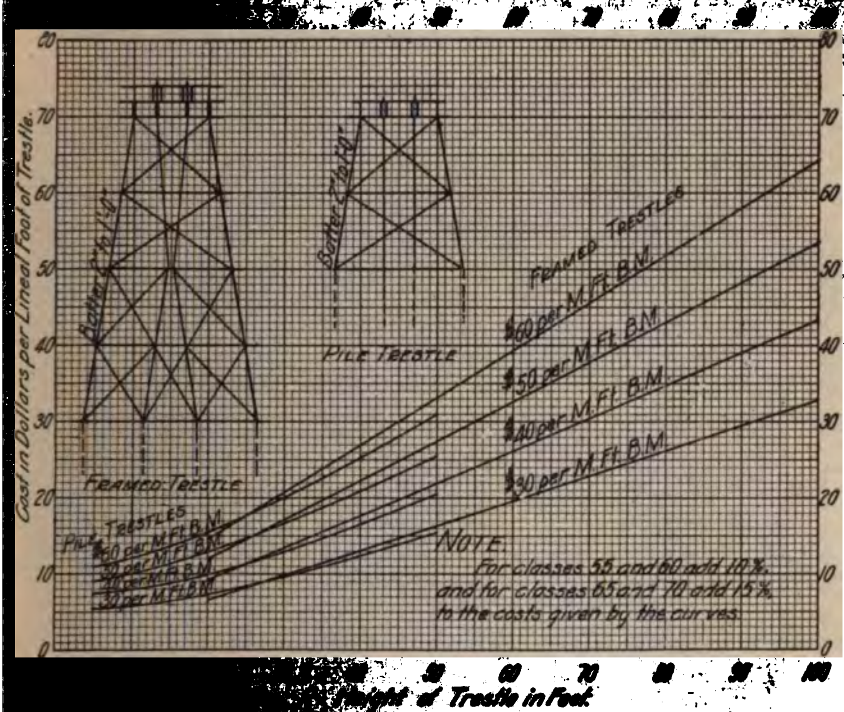
of Single-track-railway Embankments.



NOTE
Roadway-30' wide
Side Slopes-1½ to 1.
Ties 7"×9"×9'-0" 1'-8" Centers
Rails 90# per yard.
Ballast 12" deep under ties.
The cost of ballast and track in place is double that for single track railway. See Fig. 53 a.

Fig. 53*b*. Cost of Double-track-railway Embankments.

the inner hips should generally be from
of the total span length; and
should generally be from one-sixth (1/6) to
Of course, the æsthetic features of the design



NOTE.
For classes 55 and 60 add 10%,
and for classes 65 and 70 add 15%,
to the costs given by the curves.

not track rails.
14′ 0″, and for framed trestles, 28′ 0″.
to have a 10′ penetration, and to cost 35 cents

each costing 35 cents per lineal foot, are provided

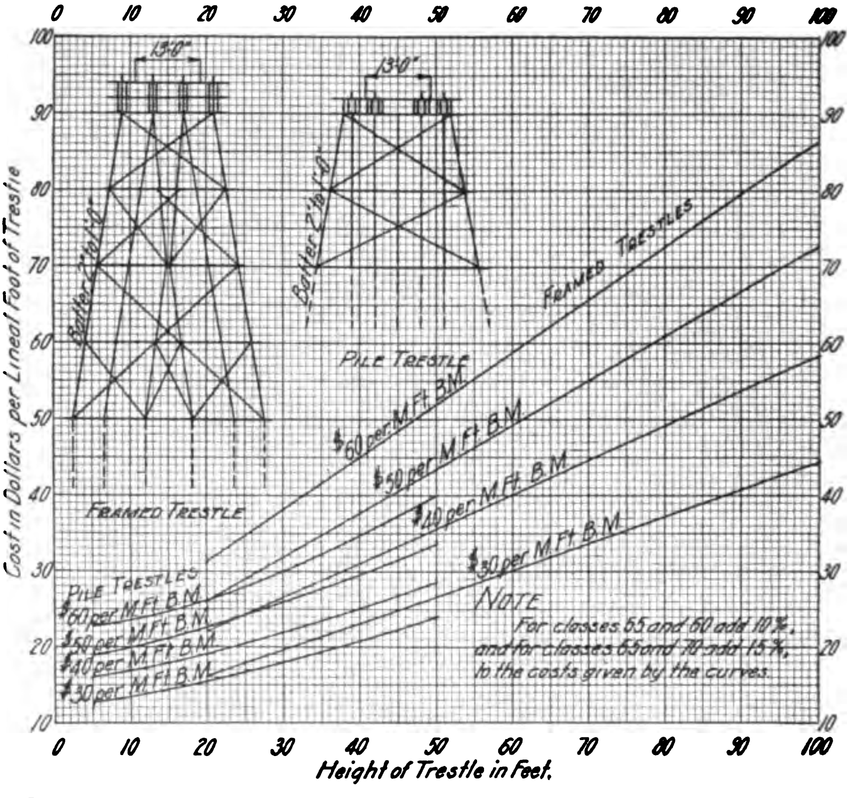
Single-track-railway, Wooden Trestles.

determination of all these depths; and, for-
in them does not affect materially their

that, as far as is consistent with safety, the
should be made as small as possible, not
of metal, but also because it reduces the
cost, of the pivot pier. For spans of moder-
generally a small economy in centre-bearing
ones, especially as the former sometimes
but the difference is often inconsiderable.
centre-bearing swing-spans due to the ob-

jectionable feature of concentrating great loads upon small areas and to the necessity in the case of very wide spans for excessively heavy cross-girders. The question of economics between the two styles of swings is one that has to be determined for each special case as it arises by preparing actual estimates and not by *a priori* reasoning.

As mentioned in Chapter XXV and previously in *De Pontibus*, the economics of cantilever bridges formed the subject of a special investigation for that treatise, the result of which was as follows:



Cost includes trestle complete, but not track rails.

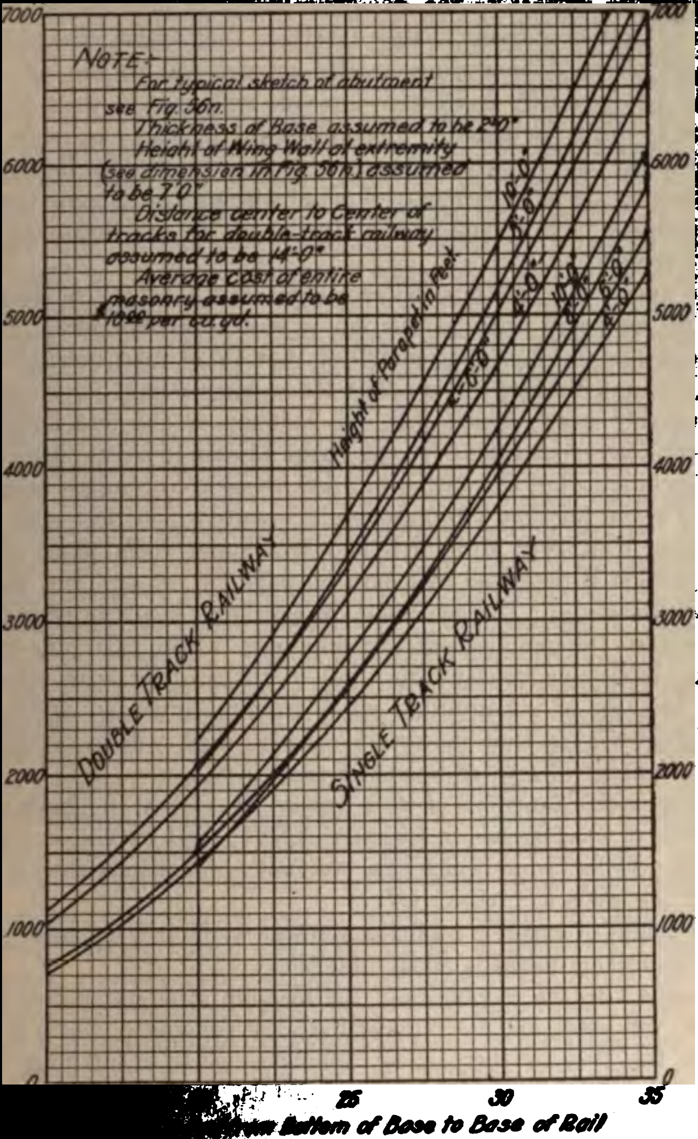
Panel lengths for pile trestles are 14′ 0″, and for framed trestles, 28′ 0″.

In pile trestles, piles are assumed to have a 10′ penetration, and to cost 35 cents per lineal foot.

In framed trestles, two 20′ piles, each costing 35 cents per lineal foot, are provided under each post.

FIG. 53*d*. Cost of Double-track-railway, Wooden Trestles.

First. The economic length of the suspended span is about three-eighths ($\frac{3}{8}$) of the length of the main opening, but a considerable increase or decrease of this proportion does not greatly change the total weight of the metal.



of Plain-concrete Railway-abutments.

is one-fifth (⅕) of the said total length. short the top chords may be built of eye- usual allowance for impact there is no re- effects quite an economy of metal. But

It is conceivable that cases might arise where, from [illegible] of falsework, eye-bar top chords would be objectionable; [illegible] method of economizing must be used with caution.

Third. In respect to the economic length of anchor-spans [illegible] cession of cantilever spans, it may be stated that within reasonable [illegible] the shorter such anchor-spans are the greater will be the economy [illegible] volved; but generally navigation interests will prevent their being [illegible] as short as might be desired. If permissible, they may be made so [illegible] that, as in the case of anchor-arms, eye-bars may be used for the tie chords, thus effecting a decided economy of metal, although shortening the anchor span increases proportionately the stresses on the web members and the weights thereof.

The question of what is the economic limit of length of simple truss spans as compared with cantilevers is still a mooted one. Professors Merriman and Jacoby, on page 119 of Part IV of their excellent [illegible] on "Roofs and Bridges," state that the economic limit for simple spans was probably nearly reached in the building of the five hundred and eighty-six (586) foot span over the Great Miami River at Elizabethtown, near Cincinnati; but the author has had occasion to compare simple truss spans of seven hundred (700) and eight hundred (800) feet with the corresponding cantilever structures and has found them more economic[illegible] This question is discussed at length on page 587, *et seq.*, and the [illegible] is referred thereto. The continuity of cantilever spans in [illegible] loads lowers the requirement for minimum width from one-twentieth ($\frac{1}{20}$) to about one twenty-fifth ($\frac{1}{25}$) of the greatest span length [illegible] hence, because of substructure considerations, gives an advantage [illegible] the cantilever type that in certain extreme cases will more than [illegible] its disadvantage of greater weight of truss metal.

The economic functions of steel trestles are treated in Chapter [illegible] and those of steel arches in Chapter XXVI; and curves of weight [illegible] metal in trestles, from which the economic proportions thereof can [illegible] derived, are given in Chapter LV.

The height of concrete retaining walls at which it is economic to [illegible] to use reinforcing metal is about (20) feet.

In respect to the economics of the medium steel specified in C[illegible] LXXIX, soft steel, and the standard steel of commerce, which is [illegible] between the two, as there is no difference worth mentioning [illegible] the pound prices of the three rolled metals, and as medium [illegible] properly be stressed the highest, it is evident that it is the most [illegible] material. It is urged by some engineers that as all, or at least a [illegible] of the reaming may be omitted when soft steel is adopted, there [illegible] economy in using the weaker metal; but the author maintains that reaming or solid drilling is essential for first class work no [illegible] kind of metal be used, and that, consequently, the claim [illegible] in employing soft steel is based upon a fallacy.

adopting nickel steel for bridge build
IV.
not only affect the economic layouts of
the character of the spans to be adopted.
from washout of falsework be great, either
cantilever structure (such as described in Chapter
one of simple spans, or a pin-connected struc-
riveted one, even if the computations of cost
good luck in erection indicate that the contrary.
chance of not getting the substructure finished
weather causes a cessation or partial cessation
the layout of spans for a bridge as to increase
therefore, the expense involved by taking
delay would be in the nature of true econ-
arose a few years ago in the author's practice;
Lytton, B. C., on the line of the Canadian North-
had been prepared upon the assumption that the
spans, which were all alike, would be erected
high water of May or June could cause any dan-
contractor in bidding, fearing that the delivery
delayed, requested that a few of the girder mem-
to permit each span (except the one first erected)
pier to pier. The extra amount of metal thus
and as the bidder agreed to pay one-half of
modification was accepted. It proved to be a for-
the metalwork was late in arriving, and the
cantilevering during the high-water period.

main members of bridges, and even occasion-
economies may be effected by choosing the
sections. Plates and angles are at times
I-beams, and at other times more expensive.
and are always difficult to obtain. Deck
priced, and tees are generally so. Many de-
I-beams over fifteen (15) inches deep cost
pound more than those fifteen (15) inches
angles having one or both legs longer than
same increase. There is a long list of special
Not infrequently it will be cheaper to use
even though more weight be involved; and
of 7″ × 3½″ section are always more expen-
being more difficult to obtain. Current
are to found in *Engineering News* the first
extras for wide plates is given on page 327
of the United States Steel Corpora-
prices of the numerous shapes of bridge

[illegible] are less than they [illegible] to make a material difference in the cost [illegible] and other foreign work, very large differences [illegible] selection of the material, owing to the variations [illegible] It behooves the expert bridge designer to keep posted [illegible] in metal prices and import duties for the different [illegible] The Bethlehem Steel Company manufactures, by means of a [illegible] vertical and horizontal rolls acting simultaneously, some special [illegible] I-beams that are exceedingly light for their strength; and [illegible] the company asks a small extra price for such sections, it generally [illegible] economical to employ them.

The duplication of a whole structure, or any parts thereof, effects a large proportionate saving in the shop. Of course, if two spans [illegible] can be made alike, entire groups of drawings are saved [illegible] a large part of the function of the detail shop draftsman to duplicate individual parts and to group partially unlike members. The [illegible] remembers the detailing of two hundred and fifty-six (256) [illegible] the Union Loop Elevated Railroad on one sheet. The [illegible] not all alike; in fact, there were many different models, but the [illegible] were so classified that they could be reduced to a system, and the [illegible] work was very greatly cheapened thereby. By duplication, [illegible] to a saving in drawings, there is a saving of templets, a saving [illegible] supervision, a saving of the writing of shop bills, a saving of [illegible] material lists, a large saving in errors, and a considerable [illegible] field due to the avoidance of loss of time in the selection of [illegible] parts; for if there is much duplication, there is much more [illegible] of the right part being at hand. Duplication extends into [illegible] details; in beam work the end connections are made alike, and [illegible] of being shown on the drawings, their numbers only are given. [illegible] the templets for such end connections are made permanent; [illegible] too, are referred to only by number and are used over and [illegible] On large structures, batten plates, lattice bars, and other similar [illegible] repeated elements can be duplicated with great advantage. For [illegible] identical lattice-bars save the resetting of the gauge on the [illegible] punch, and also the labor of selecting in assembling the [illegible] sides considerable expense in handling. It may at times [illegible] material to duplicate the parts of a structure, and yet it may [illegible] saving in the cost of construction; for, although the metal be [illegible] the pound, if the evidence of duplication of shopwork is made [illegible] the drawings submitted to bidders, a lower pound price will be [illegible]

Blacksmith work of any kind is always the most expensive [illegible] bridge shop, and it should be avoided to the utmost, not [illegible] it is not commonly well done but also because it costs [illegible] drawing room, in the templet room, in the forge shop, and [illegible] fitting, and assembling. If forging is essential, it should be [illegible]

[illegible] the saving [illegible] of the flange angles. [illegible] by hand, since they are not sufficiently [illegible] of them; but it is a common [illegible] to use forgings freely, because [illegible] forgings add to the cost of the whole [illegible] or the reverse involved in the [illegible] girders, and the officers of the different [illegible] varying ideas as to whether it is better or [illegible] economy will depend upon their length and [illegible] the question involved is whether the cost of [illegible] does not exceed that of furnishing and putting [illegible] starting to write this chapter a number of [illegible] consulted on this matter of crimping, in order to [illegible] opinion. One engineer replied, "We would not [illegible] on a lump sum contract no matter what [illegible] were over three-quarters (¾) of an inch thick. [illegible] employed, we would, of course, use crimped [illegible] feet deep or deeper." Another engineer an- [illegible] for a bridge at a lump sum, we would crimp [illegible] girders three (3) feet deep or over, providing [illegible] specified." A third engineer wrote: "We al- [illegible] stiffeners when the clear web space between [illegible] eighteen (18) inches. We, of course, would [illegible] of shorter length if the flange angles were [illegible] of light sections, if we were aiming simply [illegible] in the less amount of material; but, on the [illegible] makes a better job to use the fillers when the [illegible] allow." The cost of the freight on the filling [illegible] factor in settling whether it is finally more [illegible] crimp stiffening angles, and this feature of the [illegible] in mind by the designer. This matter of cost [illegible] portation of metal to bridge site applies to the [illegible] as well as to the question of crimping.

[illegible] difference between the lightest possible [illegible] one, not only on account of the reduction [illegible] also because of that of erection; and the de- [illegible] best possible results for all cases must be [illegible] details of both shopwork and field work. [illegible] tively what is easy and what is difficult

[illegible] manufacture and to erect; and especially should he [illegible] [illegible] can and when they cannot be driven by the various [illegible] paratus used in shop and field.

In the design of new bridges to replace old ones, the erection [illegible] be given full and thorough consideration, since a large amount [illegible] labor of replacing the old structure under traffic may be saved if [illegible] one have panels of such length as not to interfere with the metalwork of the old bridge. There are many other ways in which advantage [illegible] be gained by thoroughly considering the erection at the time the [illegible] structure is designed, such, for instance, as the supporting of the [illegible] stringers on advantageously located falsework until the new girders can be placed, and the shipping of the plate-girder spans riveted up complete instead of requiring that they be assembled in the field.

In all work of designing the cost of the materials at the site should be studied very carefully, since local prices will often enable the designer to effect a great saving. Where the work is scattered over a wide field, the matter of cost of materials becomes exceedingly important and often changes the type of the structure. For instance, in designing a highway bridge for the Western Coast, it should be remembered that steel stringers become very costly as compared with the lower priced wooden stringers of that country. The opposite conditions obtain in the eastern part of the United States. The prices of gravel for concrete work, or of [illegible] cheap stone, may affect the type of piers employed. The engineer should know markets even better than the contractor, but commonly he does not, and he will often demand expensive material where a cheaper one would serve his purpose quite as well. Rough averages of prices [illegible] unit in place are very apt to produce flaws in the economy of a design.

There is an economic feature of bridge building that is worthy [illegible] special mention in that it effects a large saving in first cost, maintenance, and repairs, often for a number of years. It is the designing of [illegible] lever brackets to carry in the future wagonways, footwalks, and [illegible] street railways, and omitting putting them in until required, but [illegible] viding all the rivet-holes for the future connections. In such [illegible] course, the trusses must be made strong enough to carry the additional live and dead loads, and the counterbracing must be figured for [illegible] future and the immediate dead loads.

A question sometimes arises as to whether it is more economic [illegible] port a pavement on buckled plate or on reinforced concrete. [illegible] is cheaper for trestles and short spans, but not for long ones. [illegible] the deterioration of the buckled plates, due to moisture and smoke, [illegible] should receive adequate consideration. Moreover, the latest [illegible] shows that very heavy concentrated live loads are liable to [illegible] buckled plates and break up the paving.

Some of the most modern problems in bridge economics [illegible] due to the advent of reinforced concrete construction. For [illegible]

the general question as to whether
concrete or steel; and for spans under
when due consideration is paid to the factors
and repairs, the former will usually be
In the future this limit of span-length for
continue to increase; and probably even today
localities.

in reinforced concrete construction it is
arch or the girder type. Unless the spans are
generally be the cheaper, but the former is the
by curving the bottoms of the concrete girders,
Street Trafficway Viaduct in Kansas City,*
be secured.

problem is whether to adopt a wooden or a rein-
steel highway bridge; and, when danger from
etc., are considered, the decision should in-
the permanent construction.

of partial destruction by fire of several large
creosoted block pavement resting on creosoted
arisen as to how much more it would have cost
reinforced concrete. The layman has an idea
small, being merely the difference between the
concrete slab and that of the creosoted planks;
the case, for the large difference between the
adds materially to the dead load that has to
system and the main girders or trusses. Some
by the author from the records of two of his
at Vancouver, B. C., both of which have lately
ones by German sympathisers, and one of
severely damaged over a length of two or
that the substitution of the reinforced concrete
would have increased the first cost of the
per cent. In these days of bridge incendi-
be good policy to employ the more expensive
adopt an asphalt or bitulithic wearing surface
although the latter are far superior in every
from danger by fire. However, it would
gration in a block pavement that rests on a
air could not readily get at the wood. A fire
would make very slow progress and could

duct, the question sometimes comes up as to
bents of reinforced concrete instead of steel;

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tration of this structure see Chapter LII.

[illegible] greater than forty or fifty feet [illegible] reinforced covers the steel will generally [illegible] beams of reinforced concrete attention must be [illegible] effect of longitudinal thrust, and this is likely [illegible] factor in the determination of the [illegible]

There is an economic question to which, as yet, but little [illegible] been paid, viz., the comparative costs of cantilever and suspension bridges. Until 1914 nothing of any value had been published concerning the length of span at which a suspension bridge becomes cheaper than a cantilever, each bridge specialist having had a vague idea of his own concerning the question. The author for years has believed this limiting length to be in the neighborhood of 2,000 feet, but has recognized that it will vary considerably for different crossings on account of the governing conditions. If the question were one of superstructure alone, it would readily be capable of solution, but the substructure plays an exceedingly important part therein, as can be seen by the following reasoning, which, perhaps, some reader may term a *reductio ad absurdum*.

Let us assume that for a certain crossing we have determined the length of main opening at which the costs of the cantilever and the suspension types are equal and have prepared a layout for each. Then let us raise the grade on them both fifty feet and make another comparison. There would be no material change in the costs of the superstructures, but there would be in those of the substructures. The main piers alone for both types would be augmented in a similar manner, provided the back-stays for the suspension bridge retained their original inclination. However, as the inclination of these back-stays would have to be increased, the load on the columns and the main piers for the suspension bridge would be augmented thereby, increasing their cost over those for the cantilever structure. There would probably be comparatively little increase in the cost of the anchorages for the cantilever bridge, as their heights could be augmented without material addition to the [illegible] But the cost of the anchorages for the suspension bridge would be materially increased to provide for the additional uplift due to the [illegible] inclination of the back-stays—then the cost of the suspension [illegible] would be greater than that for the cantilever layout for this [illegible] structure, and the length for equal costs would be increased.

Let us take another example: Suppose that there are two [illegible] crossings just alike, that in one the surface material is solid rock [illegible] out, but that in the other the foundations *for the abutments* are [illegible] necessitating the use of a great number of exceedingly long piles [illegible] opening of equal cost in the two types of structure be determined [illegible] rock profile, it will certainly be too short for the other; because [illegible] the soft foundation acts as no special hardship in the case of [illegible] lever anchorage (owing to the load thereon being vertical [illegible]

[illegible]

ent to determine the [illegible]
and suspension bridges. In order to [illegible]
of the problem he had to make [illegible]
absolutely correct. Without [illegible]
evident that the professor has made [illegible]
probable assumptions were so [illegible]
must be taken with a liberal allowance
conclusion on this point reads as follows:
for cantilevers extends from the upper [illegible]
of 1670 feet. Beyond this value, the cantilever [illegible]
type, although yielding a probable profit [illegible]
feet."

[illegible]
for his estimates on both types of structure
stronger than carbon steel, while the au-
practicable to procure the alloy with an excess
Again, the use of nickel steel was confined
the author finds that for ordinary conditions
economic to employ it in the floor system, es-
it is important to reduce the dead load to
makes the difference in pound prices between
steel, erected, 2.4 cents. This ought to be too
55,000 lbs. elastic limit, for Mr. Hodge built his
the basis of 1.65 cents per pound excess.* Dr.
(60) per cent of his long-span trusses of nickel
adopts a percentage of seventy-five (75). In de-
the cantilever bridges Dr. Steinman uses only
steel will generally be more economical. All
the question at issue; and it is probable
implied were incorporated, the span-length for
investigator would be considerably greater. In
opinion indicated in the foregoing, the author
good and valuable work done by Dr. Stein-
his little book. It certainly will prove of great
are concerned in the designing of long-span

tion in bridge engineering that has arisen of

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ing an elastic limit of 50,000 pounds per square inch,
eight-tenths (0.8) of a cent for the manufactured metal-
steelwork (the latest quotation from the Pennsylvania
economic problem materially.

[illegible] years is the economics of movable spans, or the choice [illegible] ing between the swing, bascule, and vertical-lift types. The [illegible] of this question is by no means an easy matter, for it will depend upon the special conditions affecting the particular crossing [illegible] sideration. When the swing span type is pitted against either of the others, the first point to determine is what proportionate length of [illegible] opening is equivalent to the two openings afforded by the rotating [illegible] This is a matter of personal opinion, and even in one man's mind it [illegible] vary materially for different cases. Under ordinary conditions the author believes that a single clear opening twenty-five (25) per cent greater than either of the clear openings afforded by the swing type will give equally good or better facilities for navigation, and that under the worst possible conditions the excess percentage need not be more than forty (40). Unfortunately, though, neither the author nor the designer of the bridge under consideration has anything to say about deciding this point, because the court of last appeal is always the War Department. If that department deems that the clear opening or openings suggested by the designer be insufficient, it has no hesitation whatsoever in saying so and in compelling the petitioner for approval to increase the said clear opening or openings as much as its engineers consider advisable. Up to the present time the War Department has almost always accepted plans of the author's in which the excess percentage referred to has been twenty-five or even less; but its having done so in the past is no reason for assuming that its engineers will always be willing to recognize that percentage as their maximum requirement. Accepting this settlement of the question as fixed, it is practicable to compare swing spans with bascules and vertical lifts.

In most cases when swing spans and bascules are compared the result is either a stand-off or more or less in favor of the bascule. The conditions would be unusual where the swing proves to be much more economic—for instance, where the deck is very close to the water, thus necessitating a well or wells for receiving the counterweighted end or ends of the bascule.

In almost no practicable case is the swing materially more economic than the vertical lift, unless, perchance, the opening be very narrow, the vertical clearance very great, and the depth of the bed rock small—a most unusual combination. In almost every case of comparison which has occurred in the author's practice the vertical lift has proved less expensive than the rotating draw.

Considering now bascules and vertical lifts, in most cases the economic comparison favors the latter type. It always does so if the vertical clearance is not in excess of fifty or sixty feet. If the clearance be the usual one for ocean-going vessels, viz., 135 feet, the cost of the bascule and that of the vertical lift will be equal for clear openings of about one hundred feet or, in extreme cases, one hundred and twenty-five feet. The longer the movable span, the closer the deck to the water, the deeper [illegible]

vertical clearance, the greater will be the lift.

advantageously be stated concerning "Tres lack of space prevents. Enough, however, has to show the necessity for paying strict attention in designing structures both as a whole attention is called to a valuable paper from the Investment Point of View," by C. R. engineer, published in the *Engineering Record* While it was written specially for Canadian condito those of many parts of the United States; of the subject is of such excellence as to make for any engineer who is interested in highway

CHAPTER LIV

DETERMINATION OF LAYOUTS

[illegible] determination of the layout for a large structure is one [illegible] most important responsibilities in the province of the bridge [illegible] do the work in the most effective manner possible depends [illegible] experience, coupled with good judgment and the ability to foresee [illegible] over a long period of years. The general idea that the [illegible] layout is the one which makes the first cost of structure a [illegible] is a fallacy; for there are many other considerations besides [illegible] in initial expenditure that are of great importance. The following [illegible] a fairly complete list of the various items which should be carefully [illegible] sidered before settling finally upon the layout of grades, clearances, [illegible] lengths, character of substructure, and type of superstructure to [illegible] This is a long list, but it must be remembered that it is intended to [illegible] all the considerations for all cases, and that, probably, only a few [illegible] the items will apply to any particular case.

LIST OF FACTORS AND CONDITIONS AFFECTING THE LAYOUTS OF BRIDGES

A. Government Requirements.
B. Grade and Alignment.
C. Geographical Conditions.
D. Commercial Influences.
E. Property Considerations.
F. General Features of Structure.
G. Future Enlargement.
H. Time Considerations.
I. Stream Conditions.
J. Foundation Considerations.
K. Navigation Influences.
L. Construction Facilities.
M. Erection Considerations.
N. Æsthetics.
O. Maintenance and Repairs.
P. Economics.

While there is an attempt at logic in the arrangement of the [illegible] list on the combined lines of natural sequence and comparative [illegible] tance, it is impossible to state in advance for any particular case [illegible] of cases which are the items that should receive the most [illegible] Each item will be taken up and discussed in the order adopted in [illegible]

GOVERNMENT REQUIREMENTS

In Chapter L the requirements of the United States [illegible] ulating the bridging of navigable streams are treated at length [illegible] the Federal Government nor any of the State Governments, [illegible]

[illegible]

[illegible]

crossing of a navigable [illegible]
way the navigation, the angle [illegible]
the position of the movable span [illegible]
headway above high water for both the [illegible]
character and the dimensions of the [illegible]
of obstruction to the flow of water [illegible]
parts thereof below low water mark [illegible]
the War Department has certain rules [illegible]
for crossing various navigable rivers,
elastic; hence it will generally pay any con-
other engineer who intends to bridge navi-
with the local engineer of the Government
in which the proposed structure is located,
headquarters at Washington, in order to
requirements of the Government will be. Often
and logically one can persuade the authori-
regulation that appears to be unnecessarily strin-
the relation between the widths of clear
spans and bascules or vertical-lift spans
been finally determined by the Department,
solved on its own merits.

length of span set by the Government does not
has to put in a shorter span at one end of the
all the span-lengths, or else to obtain per-
equally. If the decrease be small, it is some-
the consent of the Department to the adoption

of a bridge is so low as to bring the clear-
elevation of high water to meet the Govern-
sometimes possible to persuade the Department
but to do so would certainly be bad policy,
United States Engineers is adjusted about right
drift.

of the movable span, the broad statement
length should coincide with the deepest part
are occasional exceptions to the rule, notably
permanent, or where it can advantageously be
Permission to do such shifting and to locate
would have to be obtained from the War
have something to say about the angle

of skew, as the United States Engineer Corps always [illegible] crossing, if it be practicable; hence the bridge engineer [illegible] obtain approval for a bridge on a skew of any magnitude [illegible] pared to show good reason for his request; and even then it may [illegible] granted, because, like the author, the Government engineers look [illegible] a skew bridge as an abomination.

While the Department does not pay much attention to the character [illegible] of the draw protection, it is likely to insist that it be not omitted and that its dimensions be satisfactory.

Ordinarily, also, it does not concern itself with the dimensions of the substructure; but sometimes, especially in case of a skew bridge, objection is raised to placing too much rip-rap around the piers and thus obstructing the flow of water in the channel.

GRADE AND ALIGNMENT

In most cases the grade and the alignment of the railroad or tramway are determined before the bridge engineer is called in, but sometimes it is otherwise; and there arise occasionally conditions which compel a conscientious bridge specialist to insist upon a change in either the grade or the alignment—or in both. The ideal way to adjust the grade on a structure is to carry it over unbroken and, preferably, level, thus avoiding either a sag or a hump, as either of these objectionable conditions involves loss of power due to the climbing of unnecessary [illegible] Again, any great sag causes traction stresses and a shock that [illegible] better be avoided, if practicable. The ideal alignment for a structure [illegible] not only to have it on tangent throughout its entire length, but also [illegible] continue the said tangent quite a distance away from the bridge at [illegible] end. Sharp curves constitute an invitation for derailment; and a [illegible] railment on a bridge or near the end of one is liable to prove disastrous. A reverse curve on a structure or on an approach thereto is not permissible. Where two curves in opposite directions come close together, [illegible] should be a stretch of tangent between them; and when this tangent [illegible] on a bridge, it should be made as long as possible. Sometimes it is [illegible] tirely impracticable to avoid curvature on bridges and their approaches, as in the case of a railroad following the course of a river that runs [illegible] tween high banks and having to cross it from time to time in order [illegible] avoid heavy excavations and tunnelling. In such cases curves on the approaches are unavoidable, and often it is necessary to put a part [illegible] the whole of the structure itself on curve. Such a general condition [illegible] isted on the line of the Canadian Northern Pacific Railway as it [illegible] up the Fraser and the Thompson rivers, crossing them nine [illegible] only one structure entirely on the square.

In some skew crossings, especially when the obliquity is [illegible] permissible to square the piers to the structure, thus saving [illegible]

[illegible] always advisable because of the [illegible] area of the substructure that is opposed [illegible] on a curve, or which has its approaches on [illegible] the curvature, in that it has a tendency to [illegible] the effort to avoid excessive width of super- [illegible] in length of piers.

TOPOGRAPHICAL CONDITIONS

[illegible] is sometimes influenced to a certain extent by [illegible], because a structure suitable for the heart of [illegible] appropriate in a country district, and vice versa. [illegible] involved would be a question of æsthetics, or [illegible] for sometimes it is necessary to cover over the [illegible] so as to permit it to take care also of highway [illegible] districts where the transportation of large, heavy [illegible] expensive or altogether impracticable, the layout [illegible] this condition.

COMMERCIAL INFLUENCES

[illegible] consideration that will affect the layout of [illegible] and character of the traffic of which it will have [illegible] a variety of traffic, such as steam railway, elec- [illegible] pedestrian, considerable attention must be paid [illegible] to take care of all probable combinations of [illegible] money can be saved for a client by a bridge [illegible] to handle the question; and much can be wasted [illegible] posted on this important subject. An indis- [illegible] of the latter statement is furnished by [illegible] proposed bridge to cross the Second Narrows at [illegible] layout three railway tracks were adopted [illegible] served the purpose equally well, with the result [illegible] the structure was increased about seven hun- [illegible] dollars, and the project, in consequence, was [illegible] consummation to the dim and distant future.

PROPERTY CONSIDERATIONS

[illegible] sometimes have a far greater effect on the [illegible] at all legitimate. For instance, in the case [illegible] Railroad of Chicago, engineered by the [illegible] certain high prices for land caused the com- [illegible] line as to interfere materially with the [illegible] velocity. Refusal of property owners to

[illegible] adopt an unduly long span or [illegible] type of construction from the ordinary. [illegible] a certain city street will sometimes [illegible] and layout of an approach to a bridge, and [illegible] of the bridge itself. The method of crossing [illegible] at the entrance to a bridge might alter fundamentally the [illegible] ture, a low bridge with an opening span being adopted if the [illegible] be at grade, and a high bridge with fixed spans if it be overhead. [illegible] improvements sometimes cause material modifications of plans for [illegible] posed bridges; and even projected improvements with [illegible] liable to cause troublesome interference. The author has lately encountered obstructive opposition of this nature on a big bridge project upon which he is at present engaged.

GENERAL FEATURES OF STRUCTURES

The question of whether through, deck, or half-through truss [illegible] girders are adopted is one that will radically affect the layout, but [illegible] in the line of economics, because deck structures in most cases [illegible] a saving of expense in both substructure and superstructure, in that piers are shorter than those for through or half-through spans, and, generally, the spans are narrower, thus causing a saving of metal in both the cross-girders and the lateral bracing. The clear headway required, especially for short spans, is likely to influence the layout more or less.

The possibility of using buried piers and protecting the feet of embankments near them by rip-rap will not only affect the physical appearance of the bridge, but also it will modify the economics of the [illegible]

In case a bridge is to cross a navigable stream, the layout [illegible] will depend primarily upon whether a swing, bascule, or vertical [illegible] is adopted for the opening. If a swing is employed, it will [illegible] quire an expensive draw protection, while for a bascule or a [illegible] some comparatively inexpensive dolphins, either with or without [illegible] fender walls of sheathed piles, will suffice.

The possibility of building an arch, a cantilever, or a suspension [illegible] instead of a simple span structure would affect the layout in many [illegible] physically, æsthetically, and economically.

Again, the material adopted for construction—whether masonry, [illegible] crete, steel, or timber—will have a similar influence.

The matter of shore protection is not likely to affect directly the [illegible] out for a bridge, although its use certainly does increase the [illegible] but it might be the reason for shifting the crossing to a location [illegible] the bank is better protected by nature against scour.

Finally, the layout is affected by the character of the approaches; [illegible] they may be of earth embankment, timber or pile trestle, [illegible] or reinforced-concrete girders or arches.

for so doing. The build an entirely separate new bridge superstructure on the old, or extending their tops, or, at the the superstructure in such a manner that the future.

CONSIDERATIONS

the substructure or the superstructure the layout, for it is understandable that be built in a certain limited time while not. Again, the length or shortness of free from danger of washout of false- for changing materially the layout— pin-connected spans instead of riveted ones.

STREAM CONDITIONS

of the stream that is to be crossed are more in affecting the layout. The high water are important features in the designing of diameter of the drift determine the minimum high water and the bottom of the superstruc- affecting the pier height; and the amount and constitute an important factor in the design respect to their length and the character of increasing of the cost of the piers tends, for the spans.

required to pass the probable maximum flood, XLIX, will often settle the total length of in raising the high water mark that was de- The profile of the river-bed and the of which it is composed are likely to affect piers require expensive protection of mattress the said scour. The frequency and extent the cost of building the piers—and hence also layout—as will also the questions of rise and passing water, reversal of current, and the building of levees.

the possibility of the permanent shifting

of the channel from one side of the river to the other. If this possibility exist, one of three things must be done, viz.: first, two movable spans must be provided; second, some effective method of retaining the channel in one position must be arranged for; or, third, the design must be so made that any fixed span of the structure may at any time be converted into a vertical-lift span.

FOUNDATION CONSIDERATIONS

Important also in the determination of layout are the character and the depth of the substructure foundations. The deeper the piers have to go the longer will be the economic lengths of the spans. Again, the more difficult it is to penetrate the materials overlying the bed-rock or final foundation, the greater the cost of the piers, and the longer the economic spans. The ultimate depths to foundation and the materials to be penetrated determine what process of sinking to adopt; and as the cost of the substructure depends upon the said process, so also will the layout.

NAVIGATION INFLUENCES

The influences of navigation that are likely to prevail during the time of the contractor's operations may be of such moment as to affect more or less the design and the layout of the structure; although this is not very likely. Again, the possibility in the future of greatly augmented river traffic may influence the type of movable span adopted.

CONSTRUCTION FACILITIES

The availability or otherwise at the bridge site of sand, gravel, concrete-stone, a machine shop for repairs, and a reliable source of supplies for the work and workmen, the accessibility or the contrary of the site from the nearest railroad depot or siding, the length and difficulty of wagon-haul or other means of transportation of materials and supplies, the facilities for securing and retaining labor, and the availability of supplies of timber and piling all affect greatly the cost of the substructure and to a minor degree that of the superstructure—hence also the layout of spans and piers.

ERECTION CONSIDERATIONS

The difficulties that may be anticipated for erection, and the method thereof finally adopted, whether by falsework, cantilevering, semi-cantilevering, or flotation, are important factors affecting the layout of the structure, as are also the questions of the maintenance of traffic and the replacement of an existing bridge.

ÆSTHETICS

Too often the question of æsthetics is totally ignored; but when it is given proper consideration, it may cause modifications in span lengths,

How much extra money it is … to spend for the purpose of beautifying … It depends greatly upon the designer's … in nature and in art, as well as upon the … and the extent of the influence upon him exerted … Generally speaking, the best layout for all the … best also for æsthetic reasons; but there are cases … of money, time, and brains will secure great …; and in such cases the beautifying of the … possible, be accomplished.

MAINTENANCE AND REPAIRS

… and repairs as well as that of operation may … ation affecting the layout of a structure. For … City highway bridge over the Missouri River … bridge company, in spite of the author's forcible … contract for the structure on the basis of a high bridge … timber trestle approach. Later they were con- … expense of maintaining the said trestle would be so … than the total net income from traffic receipts; … to a low bridge design.

ECONOMICS

… engineer encounters a bridge problem in which the … layout determination is really that of economics, … comparatively speaking, the case is a simple one. … pier equal to one-half the cost of the trusses … two spans which it helps to support, the greatest … obtained. A case of this kind occurred in the … Pacific Railway bridge across the North … Kamloops, B. C. As shown in Fig. 31*aa*, the … of deck, plate-girder spans, one of which is … passage of small river steamers at certain high …

… thetics often conflict with those of economics; … to let the span lengths change backward and … the vagaries of an unusual bed-rock profile; … to compute the economic span length for … and to use one length instead of several. … such an arrangement does not involve any … tioning when the cost of structure for that … for the truly economic one. The question … be finally settled by adopting simply that … cost is a minimum; because, as pointed out

[illegible] and the [illegible] annual cost of [illegible] as a minimum.

[illegible] conclusion to the general subject under [illegible] encourage young engineers, it might be well to state that [illegible] when determining the layout for any large and important [illegible] give full and due consideration to all the factors treated in this [illegible] truly worthy to be termed an expert bridge engineer.

CHAPTER LV

[illegible] of diagrams [illegible] in the author's [illegible] of much [illegible] thoroughly revised so as to [illegible] LXXVIII. In addition to the [illegible] methods of finding the weights [illegible] when the weights of the correspond- [illegible] are given. The said methods con- [illegible] formula; and these are of two [illegible] remains constant and the applied load [illegible] the other in which the load per lineal foot re- [illegible] length varies. In case that both the span [illegible] foot vary, the effect of one variation is first [illegible] weight is modified because of the other

[illegible] there are presented eleven examples of how [illegible] diagrams herein given; and they were so [illegible] of all the various weight-calculation problems [illegible] bridge engineer's practice. The reader who [illegible] of these diagrams is advised to peruse the [illegible] check the numerical calculations of all [illegible] may accustom himself to the rapid com- [illegible] bridges and trestles of all kinds and for

[illegible] submitted are for railroad bridges, but some [illegible] bridges, and others apply to both classes [illegible] the weights of rails or hand-rails included.

[illegible] RAILWAY BRIDGES

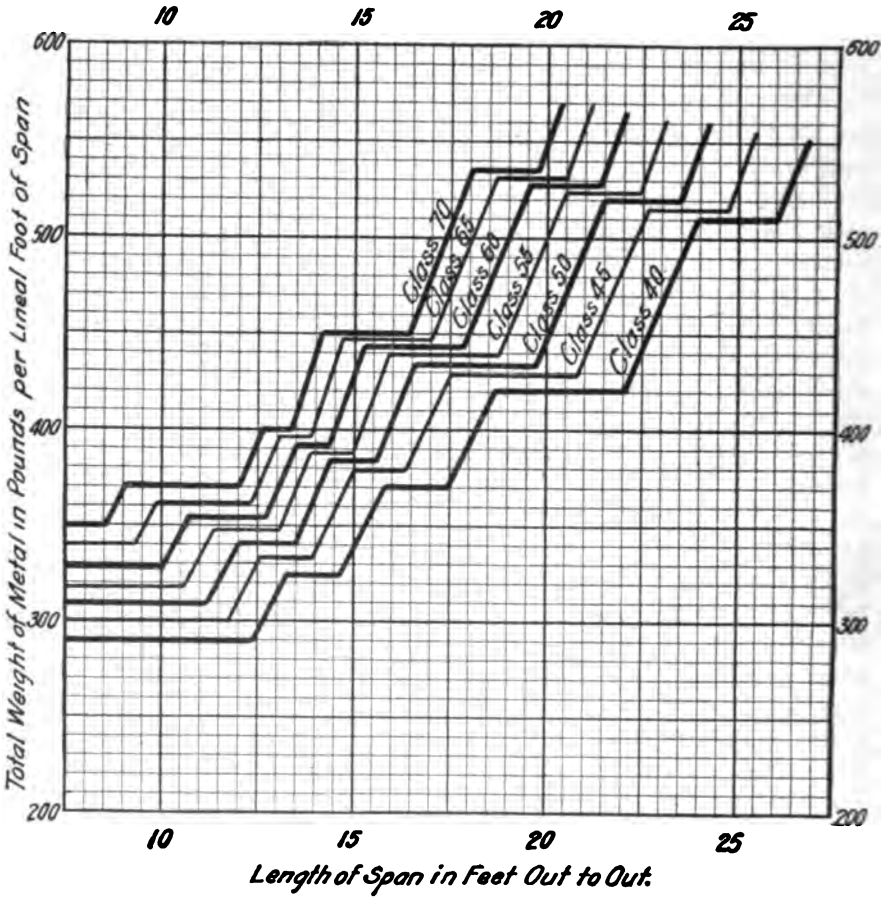
[illegible] of the diagrams will be needed:

[illegible] are four lines of I-beams per track.

[illegible]-steel pedestals are employed for spans [illegible] shoes and rollers for spans of 50 feet and [illegible] is used for spans below 70 feet. In [illegible] four lines of I-beams per track acting as

[illegible] given for the floor system include those

of the stringers, stringer bracing, end stringer brackets, and intermediate and end floor-beams. There are two lines of stringers spaced seven (7) feet centres. In respect to the metal on piers, the pedestals and the bases are of cast steel, and the weight of the pedestal pins and their nuts are included in the weights given by the curves. In respect to the lateral system, the bottom laterals of through spans and the top laterals of deck spans are of two-angle section in the form of a T with transverse single-angle struts between stringers to take up the effect of train thrust. The top laterals of through spans and the bottom laterals of deck spans are of four-angle I-section laced. The portal bracing is of the double-plane type.



NOTE.—Four beams per track used.

FIG. 55*a*. Single-track-railway, I-beam Spans—Total Metal in Span.

Figs. 55*a* to 55*q*, inclusive, give, for single-track railway bridges, the weights of metal per lineal foot of span for rolled I-beam spans; deck

[illegible]

[illegible] Pratt-truss spans, deck, [illegible]

[illegible] Pratt-truss spans; and through

[illegible] Plate-girder Spans—Total Metal in Span.

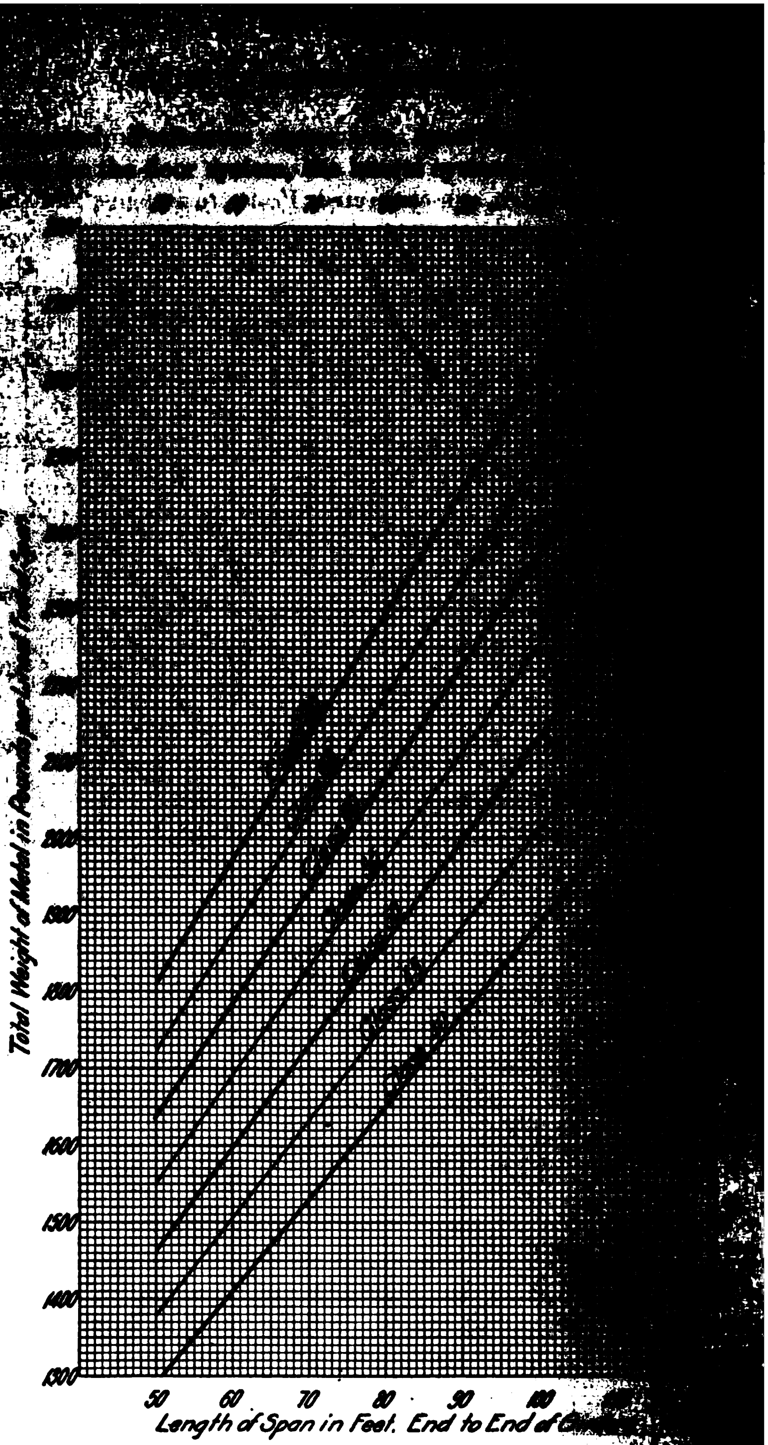


FIG. 55c. Single-track-railway, Half-through, Plate-girder Spans—

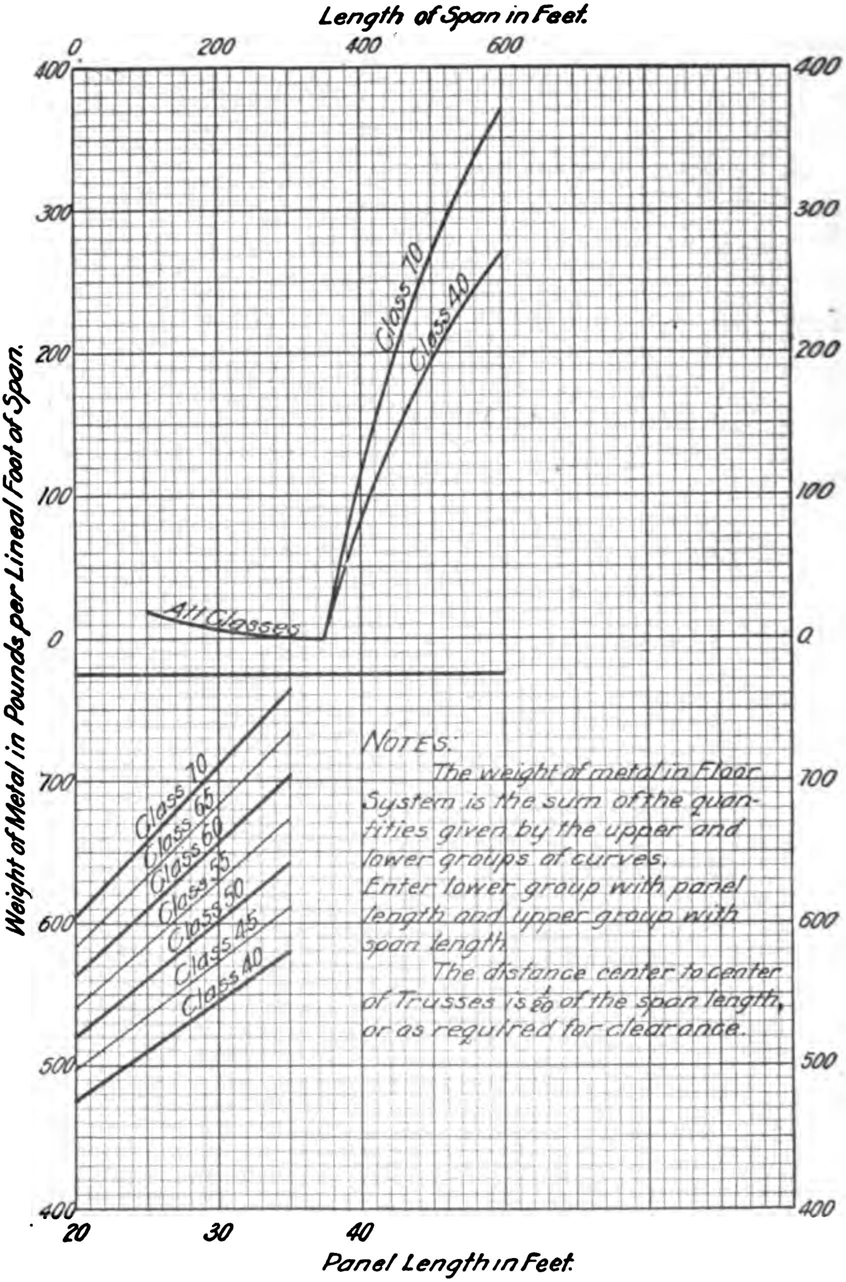
and a combination of the four groups giving the tot
per lineal foot of span in the structure. Fig. 55f give

gh, Truss Spans—Metal in Laterals and on Piers.

the actual lengths of metal. This is much determination of the exact lengths of the extra work for the computer. Should,

however, anyone desire to use the actual lengths, all the percentages given by the curves are to be increased by two.

Fig. 55*j* involves the use of "double-tracing" curves, hence it may



NOTES:
The weight of metal in Floor System is the sum of the quantities given by the upper and lower groups of curves.
Enter lower group with panel length and upper group with span length.
The distance center to center of Trusses is $\frac{1}{20}$ of the span length, or as required for clearance.

FIG. 55*e*. Single-track-railway, Through, Riveted, Truss Spans—Metal in Floor System.

by first find the panel length the exterior vertical line, then trace corresponds to the distance from centre vertically up to the curve which indicates the horizontally to the left until the outer vertical

Riveted, Pratt-truss Spans—Percentages of Metal in Truss Details.

the reading indicated will give the weight of span for the floor system of the bridge. economical of space, for it obviates many individual diagrams; and it makes the easier.

ACK RAILWAY BRIDGES

give for double-track railway bridges the usly described for single-track railway the deck truss spans; hence they require

no further explanation, except that the bottom lateral diagonals of all truss spans are composed of four angles laced in the form of an I, that the weights for double-track, deck, plate-girder spans are just twice as great as those for the corresponding single-track spans, and that the weights for

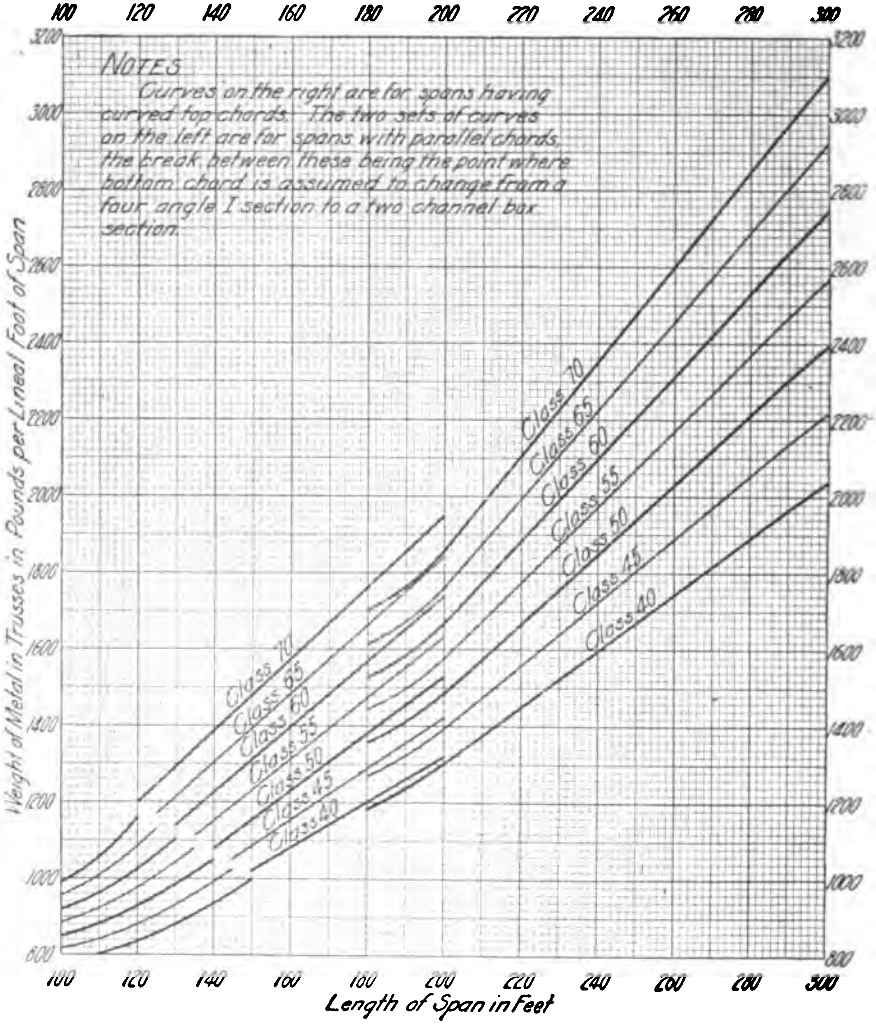
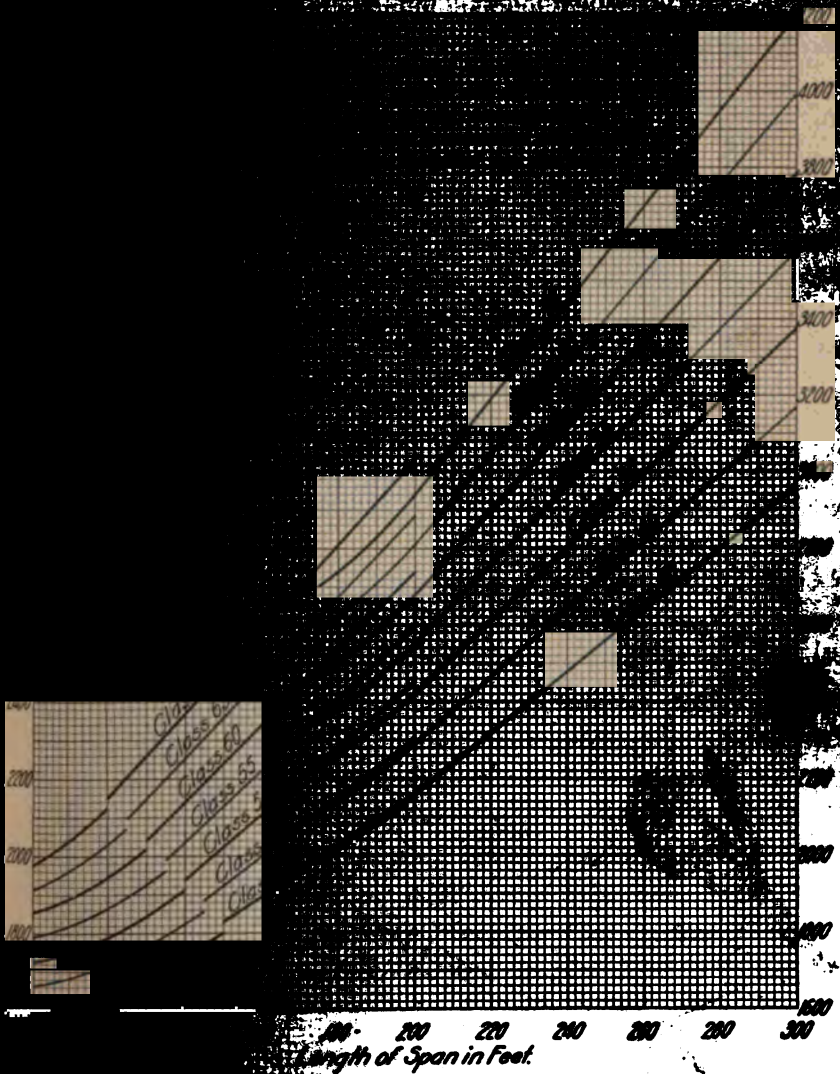


FIG. 55*g*. Single-track-railway, Through, Riveted, Pratt-truss Spans—Metal in Trusses.

half-through, plate-girder spans are less reliable than the other records because the restrictions in respect to vertical distance between clearance line and base of rail will modify materially the weight of both the floor-beams and the brackets that stiffen the top flanges of the main girders.



lway, Through, Riveted, Pratt-truss Spans—
Total Metal in Span.

that the heavier the loading the smaller true within the limits of the diagrams, which feet. It will be noticed also that most of the Were they continued beyond the 300-foot

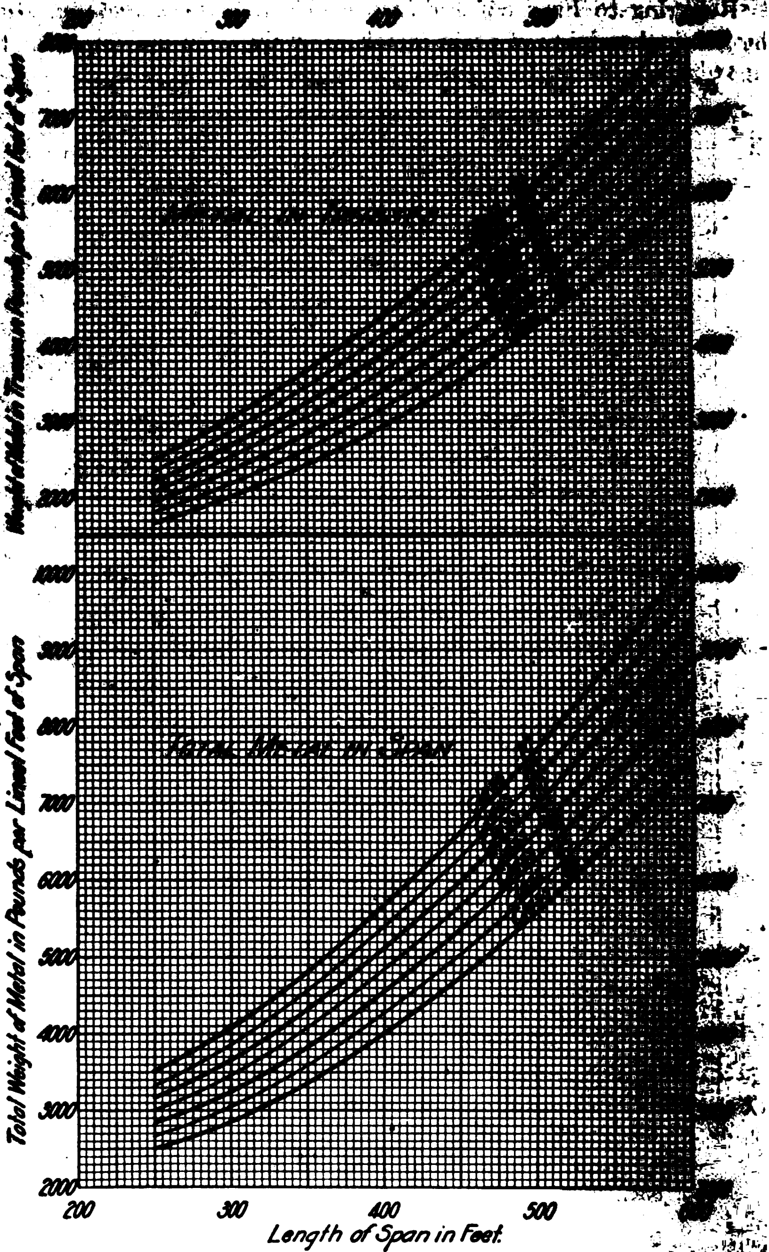
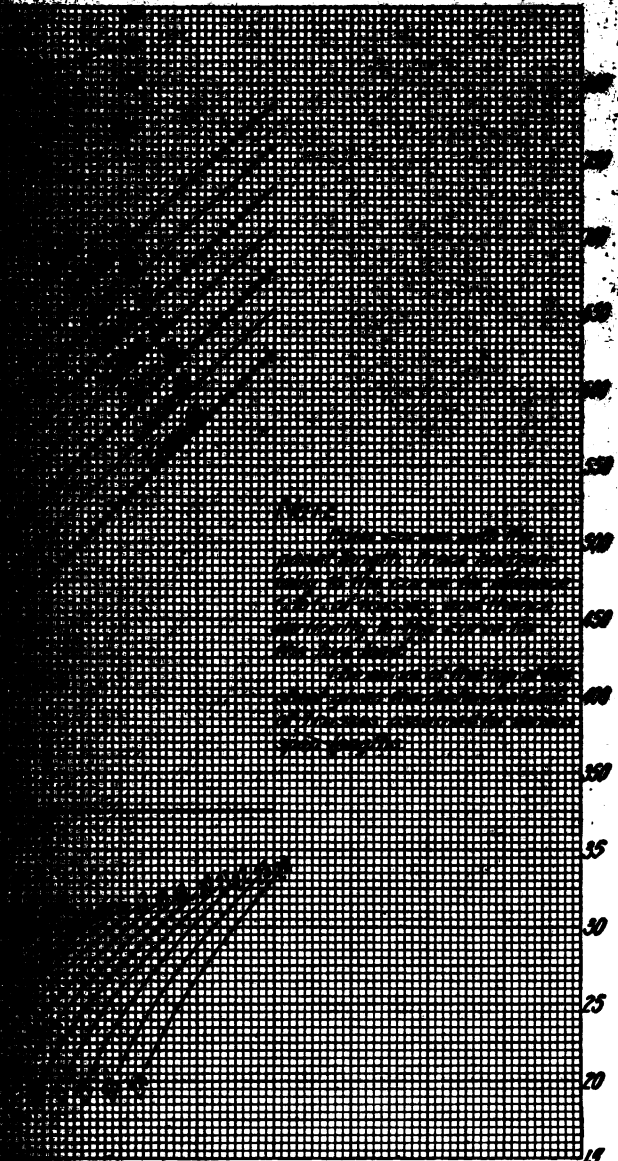


Fig. 55i. Single-track-railway, Through, Riveted, Petit-truss Spans—Metal [illegible] and Total Metal in Span.

[illegible] height to span and occasionally [illegible] thirty-five or possibly even greater. [illegible]



Deck, Riveted, Pratt-truss Spans—Metal in Floor System.

detail for riveted spans is not so much a func- of the total weight of metal per lineal foot.

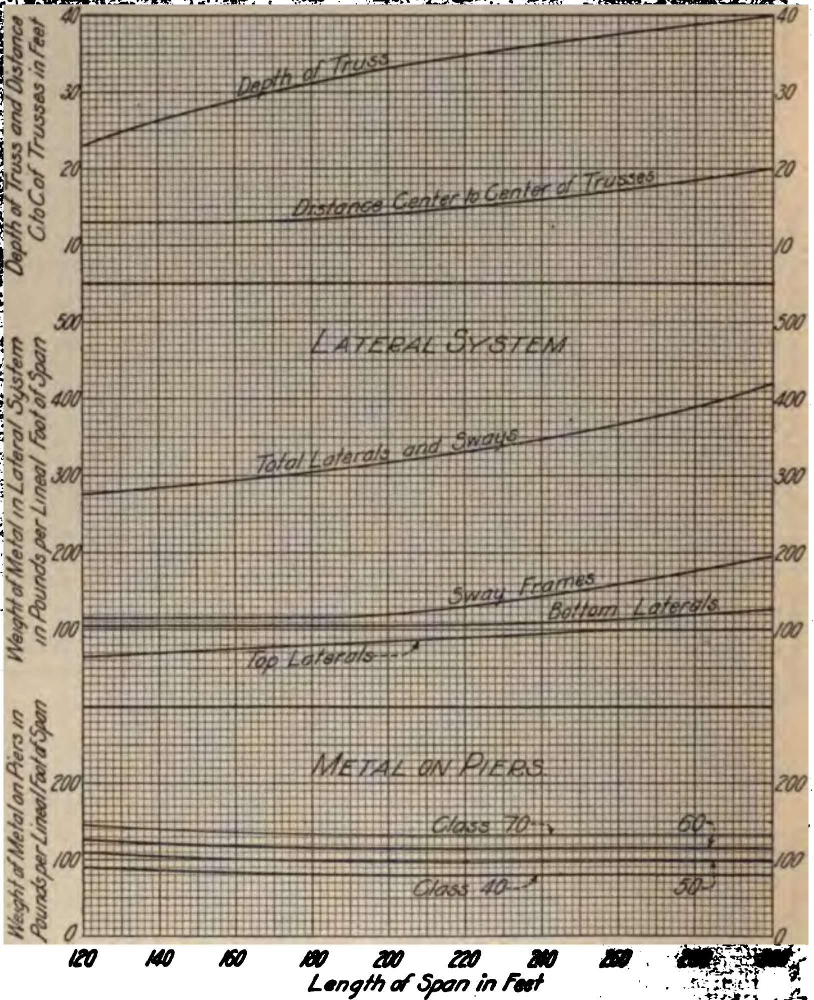
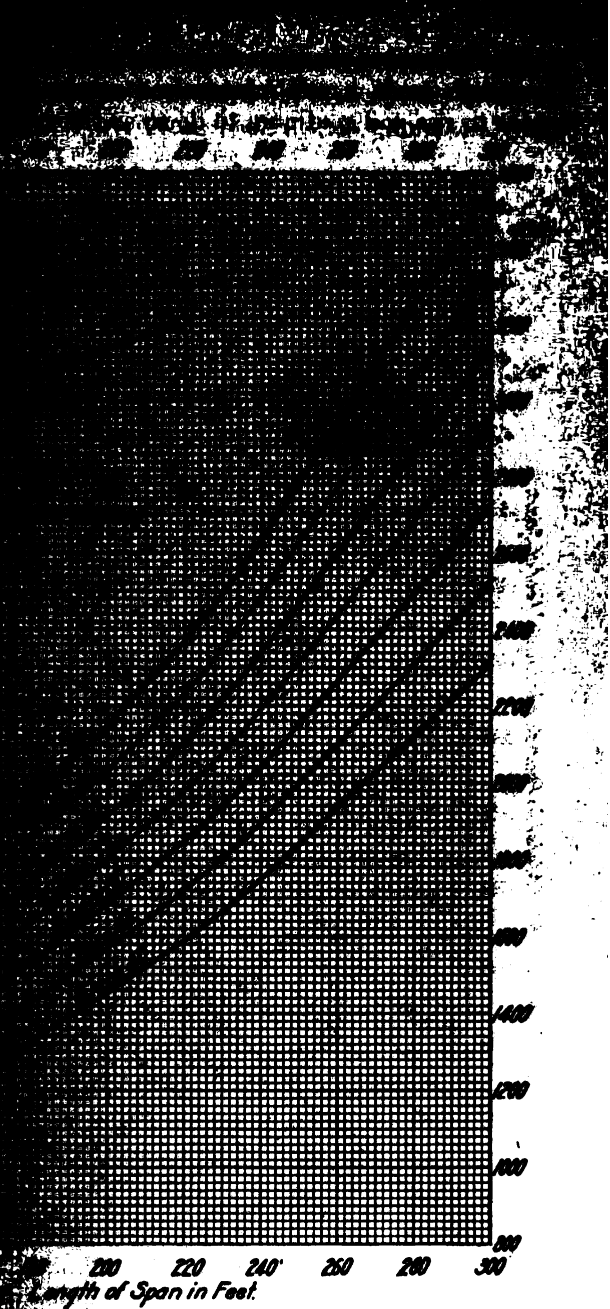


FIG. 55k. Single-track-railway, Deck, Riveted, Pratt-truss Spans—Metal in Laterals and on Piers.

lacing and batten plates (and often even the connecting plates), have proportionately larger sizes than they would have in heavier structures; [illegible] as the weight of metal per lineal foot increases, either because of [illegible] span length or on account of heavier loading, the proportioning [illegible] details is governed more and more by theoretical considerations [illegible] there is less apparent extravagance of metal in detailing; [illegible]



Deck, Riveted, Pratt-truss Spans—Metal in Trusses.

there arise conditions which cause an increase as the necessity for using diaphragms in great number of splices required in the web

[illegible] of the chords because of the inability to secure long, [illegible] the piling up of connecting plates at the intersections; [illegible] begins to rise and continues to do so as the spans become heavier and the

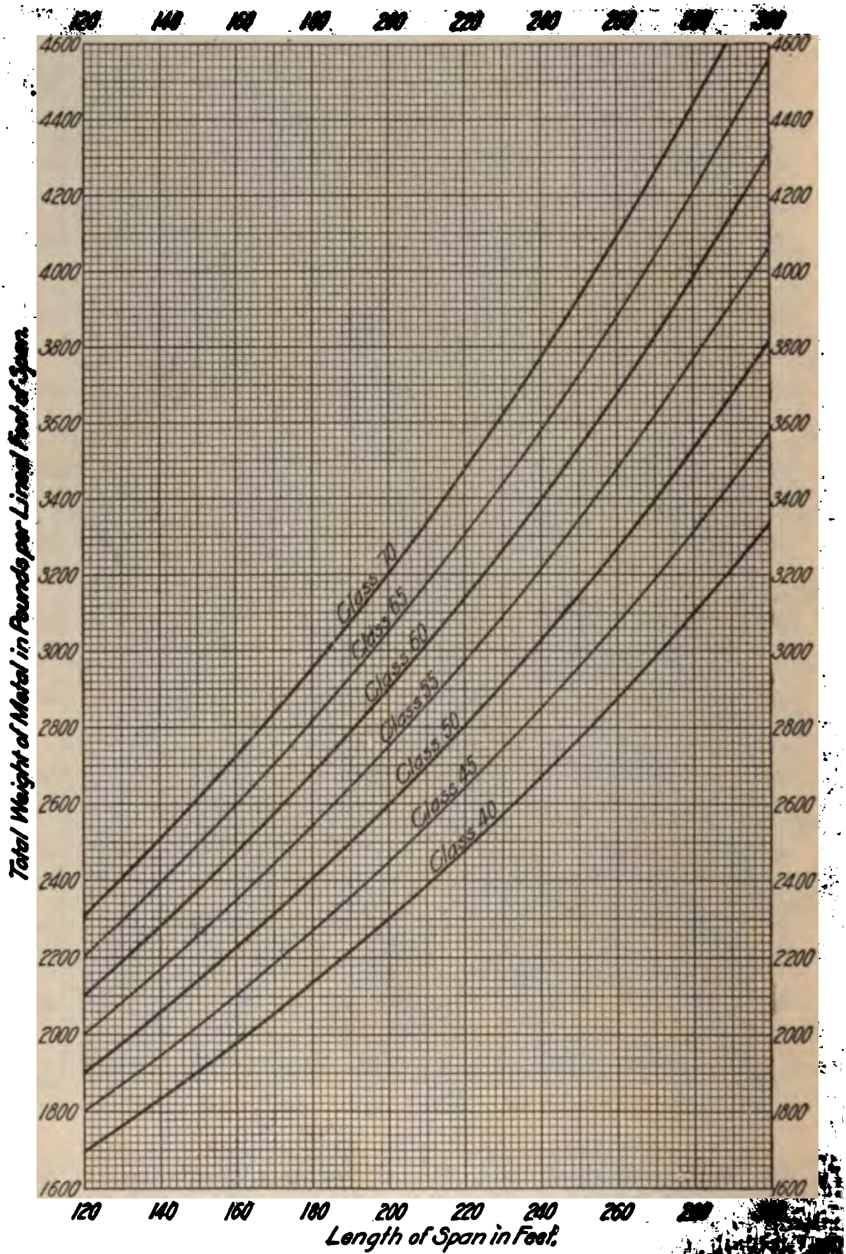
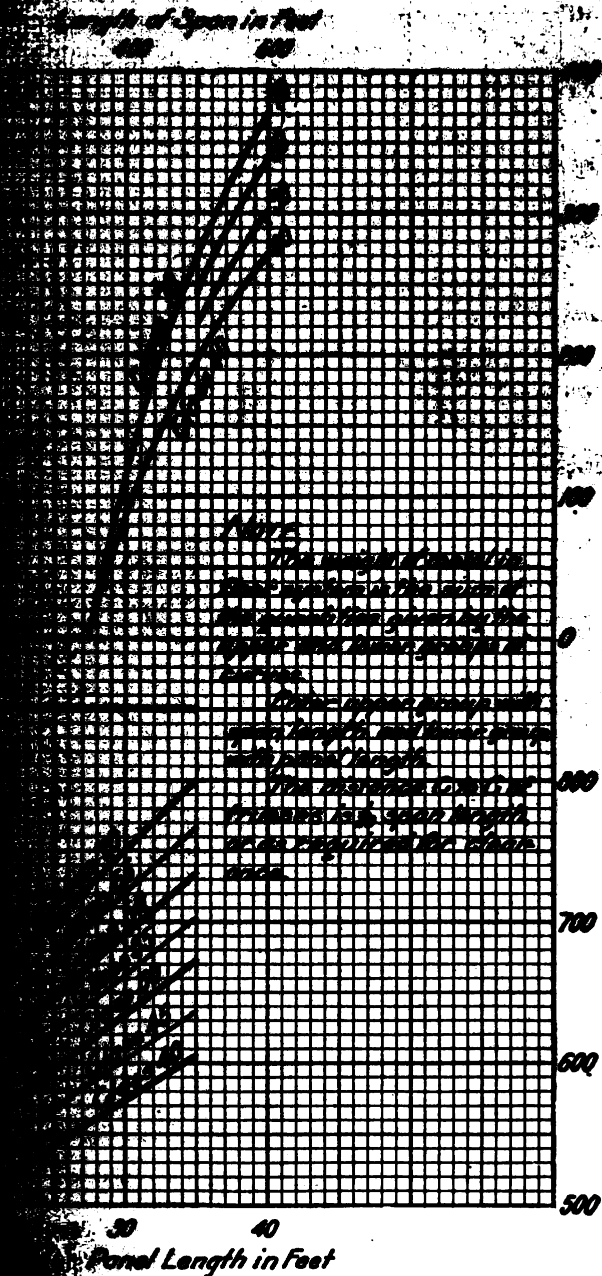


Fig. 55m. Single-track-railway, Deck, Riveted, Pratt-truss Spans— in Span.

adoption of closed box compression chords ages somewhat, but that style of detailing . For riveted trusses it is impracticable to



Through, Pin-connected, Truss Spans—Metal in Floor System.

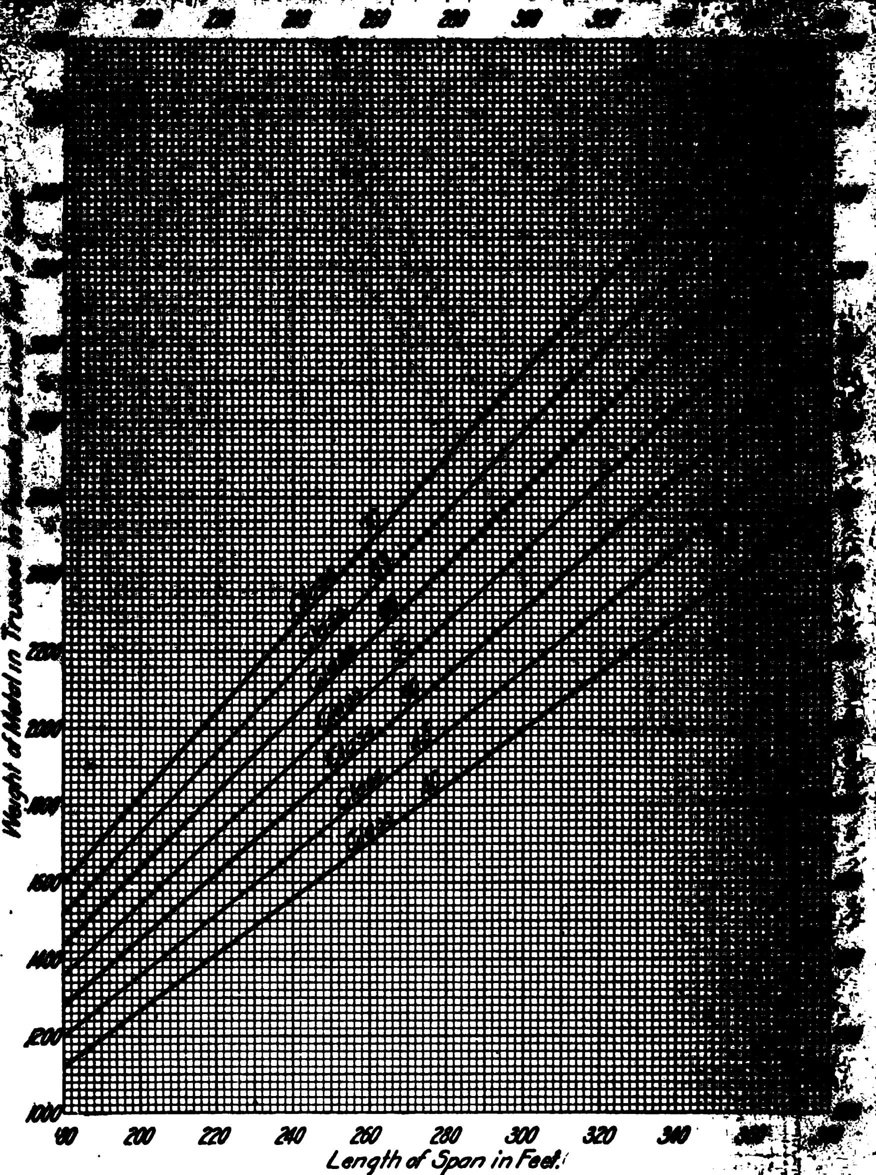
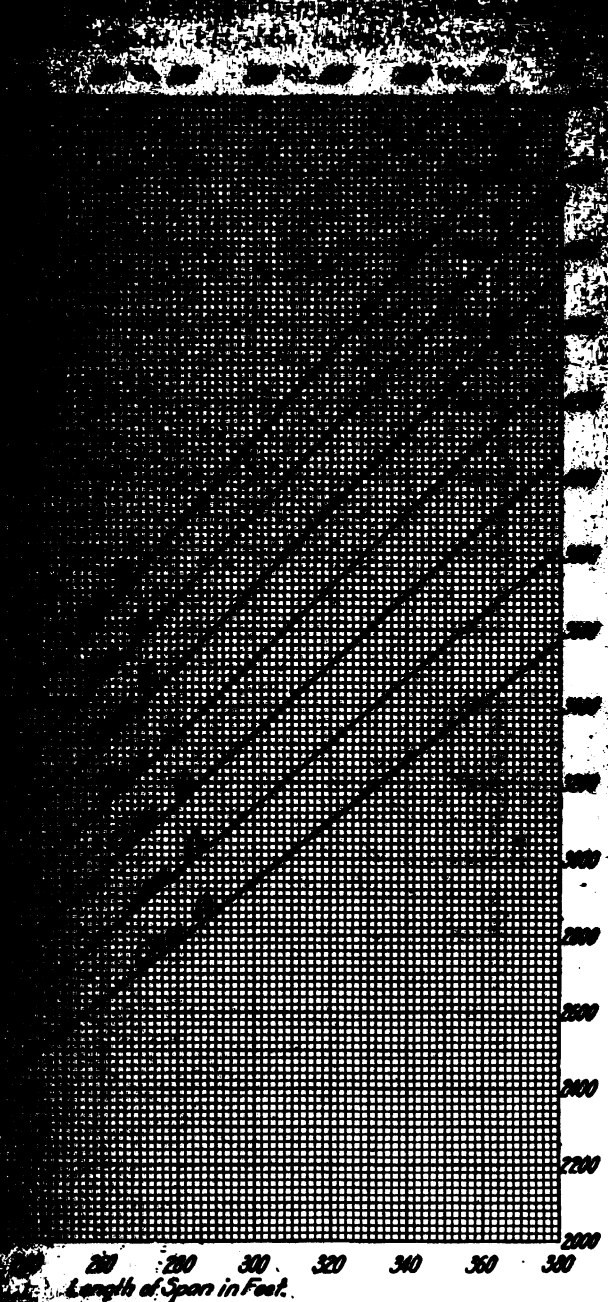


Fig. 55o. Single-track-railway, Through, Pin-connected, Pratt-truss [illegible] in Trusses.

they go. In the former diagram, which covers single-track [illegible] author would suggest that after 300′ for Class 70 or 400′ for [illegible] curves be assumed to rise gradually from about 33 per cent [illegible]



Through, Pin-connected, Pratt-truss Spans—Total Metal in Span.

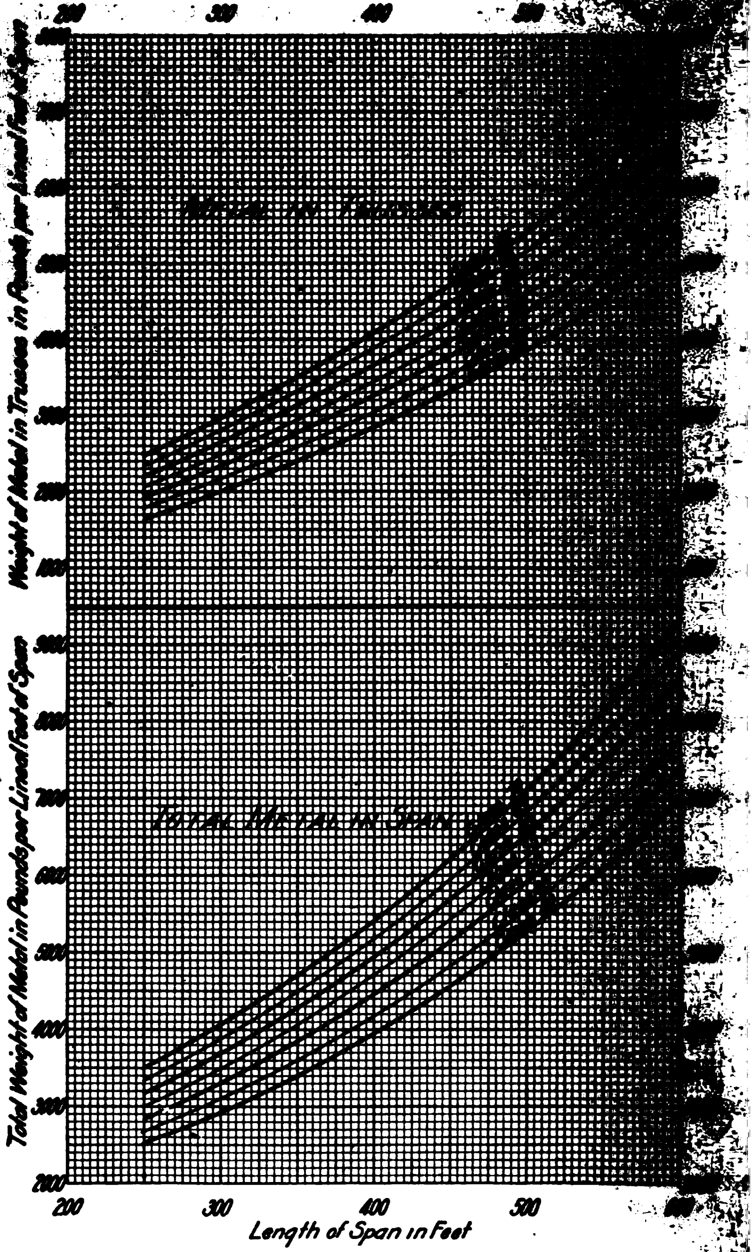
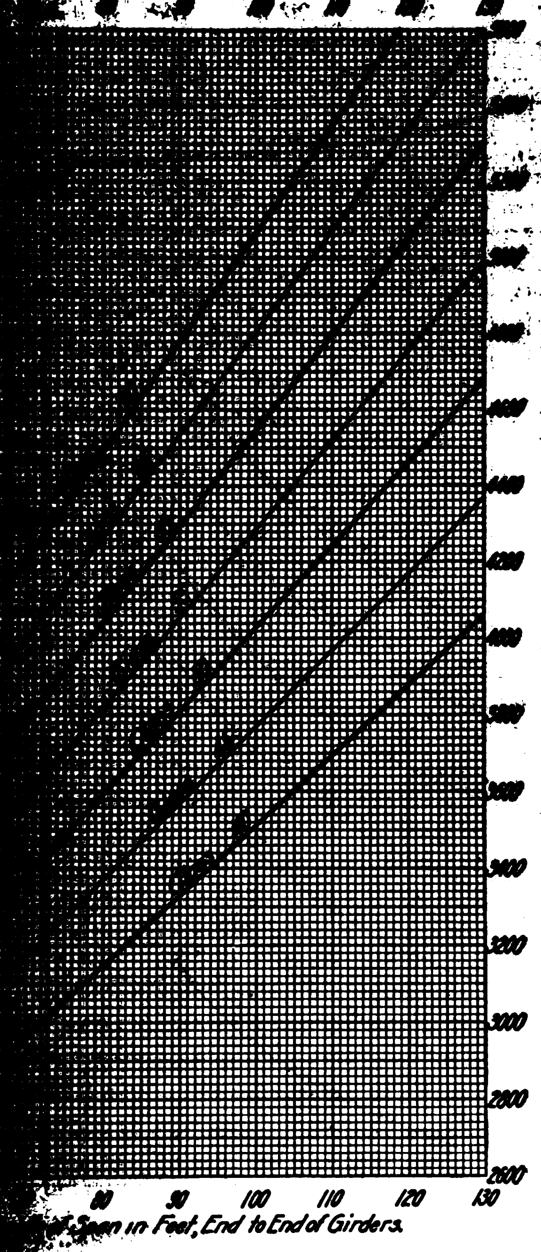


FIG. 55q. Single-track-railway, Through, Pin-connected, Petit-truss Spans—[illegible] in Trusses and Total Metal in Span.

longer than anyone in these days

span. Fig. 55a shows the double-



Half-through, Plate-girder Spans—Total Metal in Span.

their minima of 31 and 32 at span-lengths of

would suggest that these be gradually

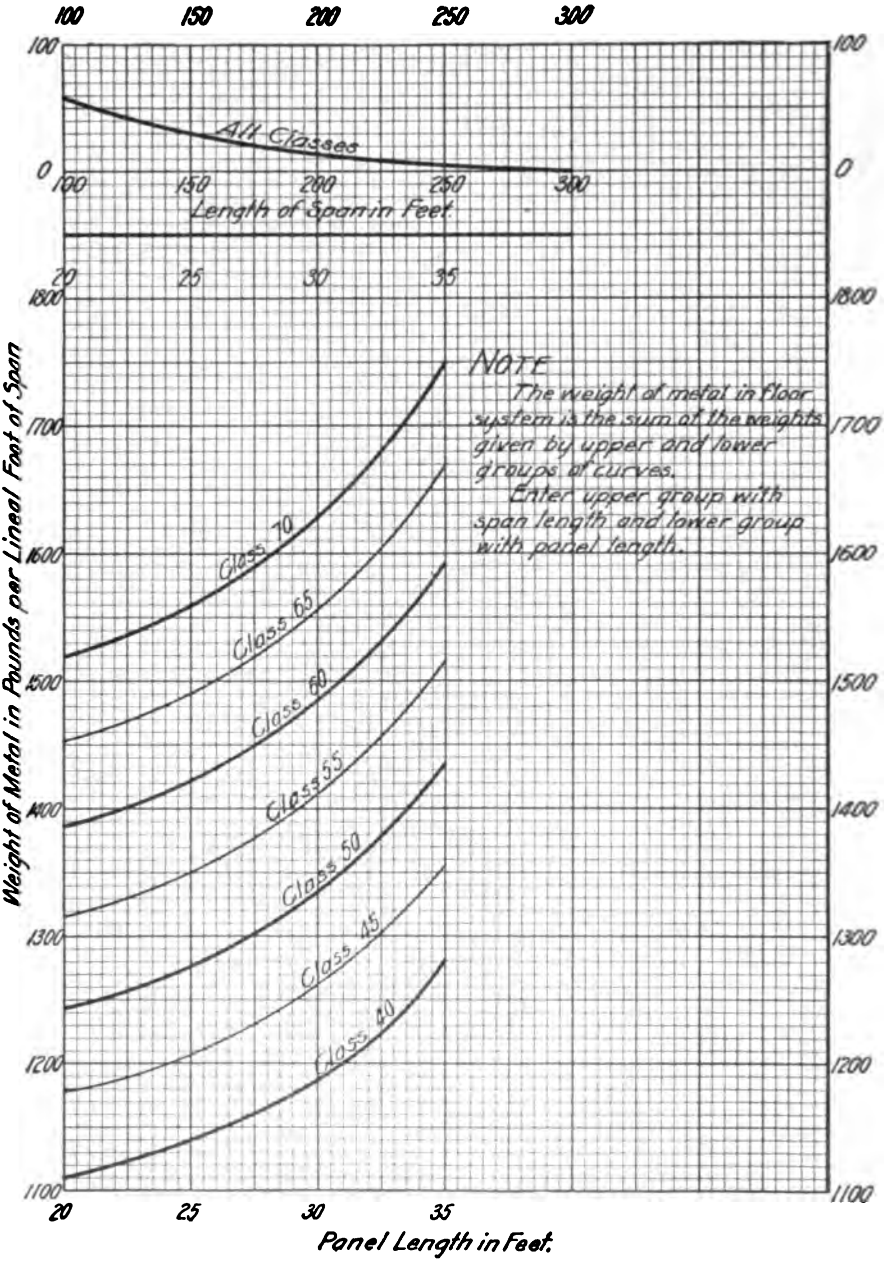
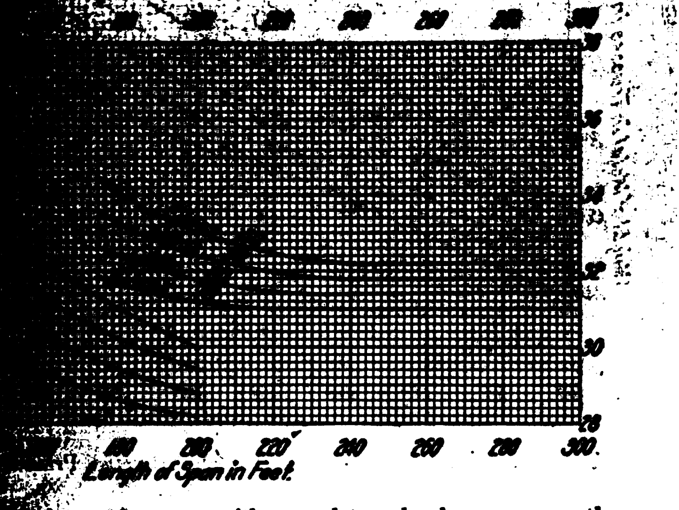


FIG. 55s. Double-track-railway, Through, Riveted, Pratt-truss Spans—Metal in Floor System.

Riveted, Pratt-truss Spans—Metal in … on Pins.



are for spans with curved top chords; curves on the chords.

stiffening diaphragms in all truss members will add about

are to be figured by using the centre to centre lengths, members. If the actual lengths are used, the percent- be increased by 2.

Through, Riveted, Pratt-truss Spans—Percentages in Truss Details.

reach 45 per cent at spans of 600 or even is almost nothing known positively about

the detail percentages for long, heavy, riveted spans believes that the figures he has given will prove to be about depends upon the personal equation and the skill of the detailer span riveted bridges are just beginning to come into vogue

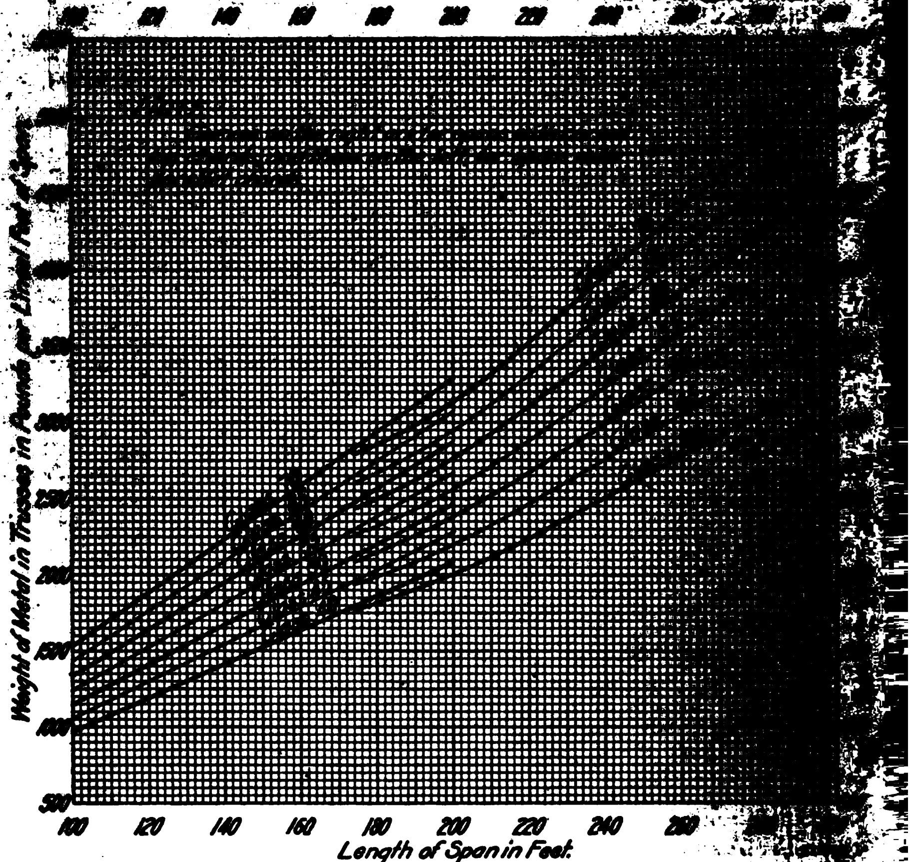
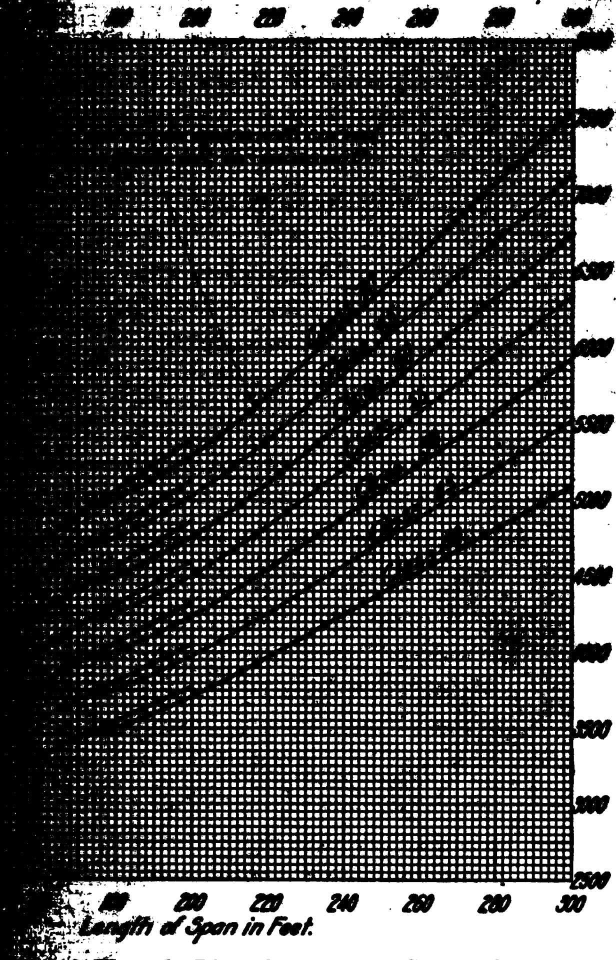


Fig. 55v. Double-track-railway, Through, Riveted, Pratt-truss Spans—Metal in Trusses.

question of percentage to add for details is likely to be an important Of course, the assumed percentage cuts no figure in the final design, but by knowing just about what is right, the computer will probably save possibly two re-figurings of stresses, sections, and weights of trusses by an excess in the resulting dead load.

In the days when he built pin-connected spans the author percentages for details varying from 32 for short, light spans down 20 for long, heavy ones; but in view of the improvements effected ing since then, and especially because of the adoption of heavy compression members, he would suggest that the

spans of 1,000 feet with proportionate spans. In pin-connected trusses there is no the percentage with the weight per foot of tible by the sudden passing to the use of



Through, Riveted, Pratt-truss Spans—Total Metal in Span.

members) as there is in riveted structures; is a gradual decrease, mainly because of the and, therefore, the smaller proportionate Again, the percentage depends more upon the of the load carried; consequently greater believes that the percentages just given for reliable and on the safe side, and that,

[illegible] weights of metal for swing spans, [illegible] [illegible] records therefor, he has decided not to [illegible]

Fig. 55x. Double-track-railway, Through, Riveted, Petit-truss Spa Floor System, Laterals, and on Piers.

that type of movable bridge is slowly but surely being su vertical lift and the bascule, as pointed out in Chapter XX there are given the following directions for finding the

Through, Riveted, Petit-truss Spans—Metal in
Total Metal in Span.

for swing spans from the diagrammed weights of [illegible] spans.

The weight of metal per lineal foot in the floor system is practically the

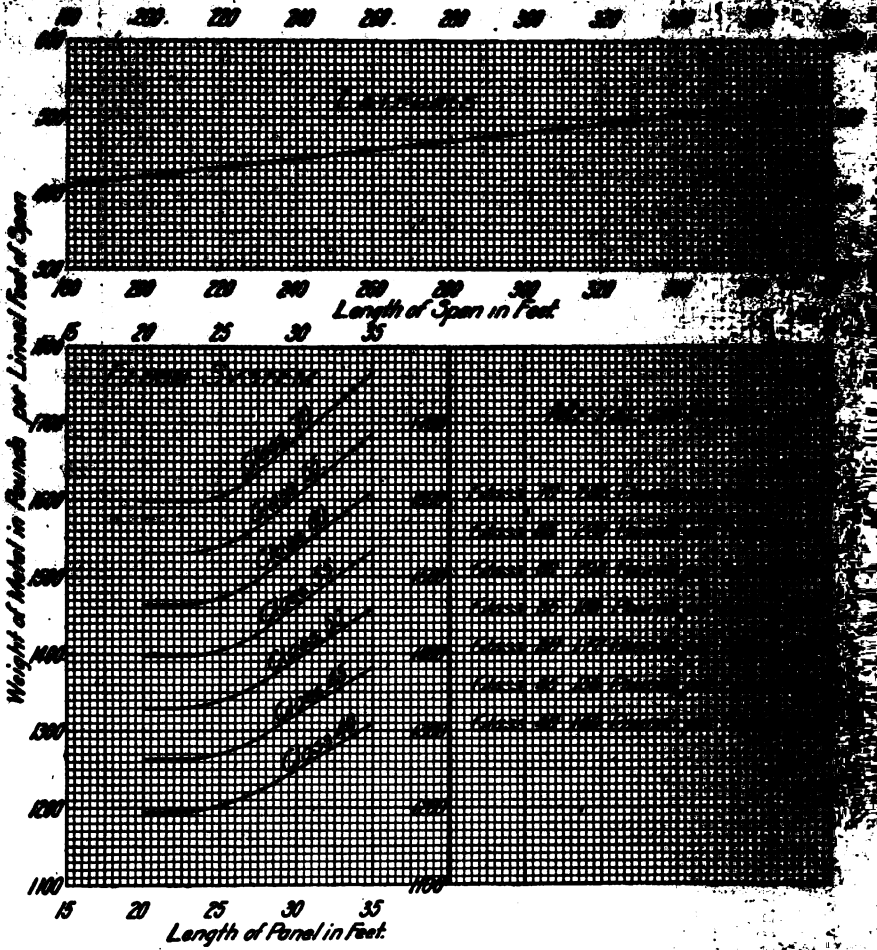


FIG. 55s. Double-track-railway, Through, Pin-connected, Pratt-truss Spans—Metal in Floor System, Laterals, and on Piers.

same as for a fixed span of equal length, provided the [illegible] distance between central planes of trusses is unchanged. [illegible] track bridge the weight can be found from Fig. 55e or Fig. 55n [illegible] to the quantity given by the lower group of curves an amount [illegible] by entering the upper group with a "span length" of twenty [illegible] perpendicular distance between central planes of trusses.

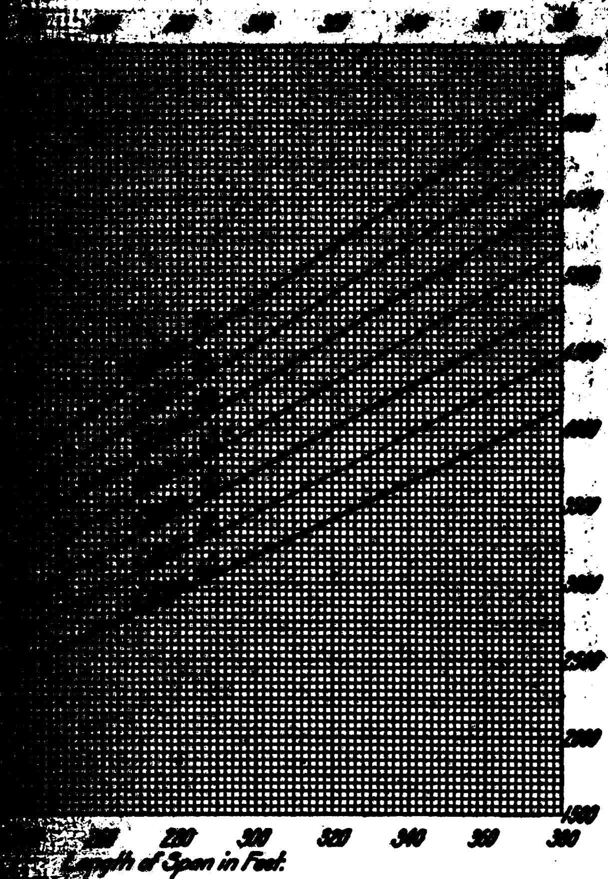
The weight of metal per lineal foot for the lateral system [illegible] span is equal to the corresponding weight for a fixed span [illegible] equal to seventy (70) per cent of the total length of the [illegible]

of the lateral system can be

as rapidly as does the width.

lineal foot for the trusses of any swing span

for the corresponding weight of a fixed span



Through, Pin-Connected, Pratt-truss Spans—Metal in Trusses.

(60) per cent of the total length of the said

the drum, machinery (exclusive of motors or rim-bearing, single-track railway bridges is combined weights of the floor system, lateral centre bearing swings the amount is somewhat sufficient data to say exactly what should to the aforesaid combined weight in order to that it is not less than twenty-five (25)

[illegible]

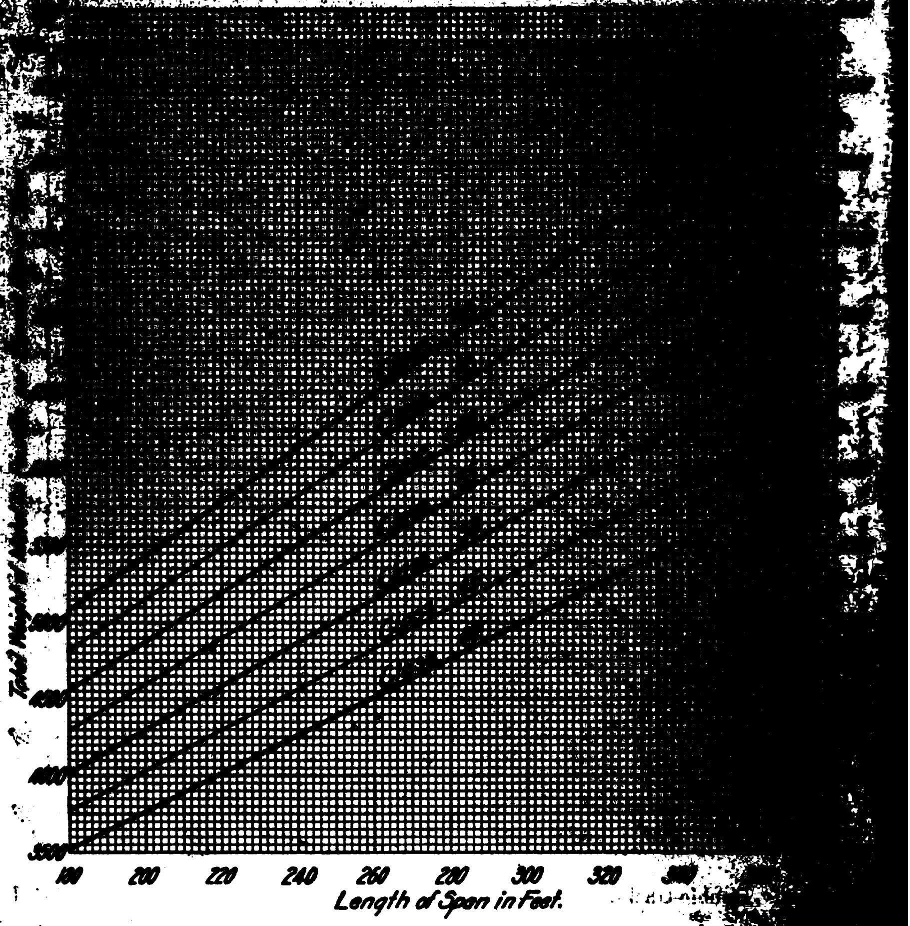
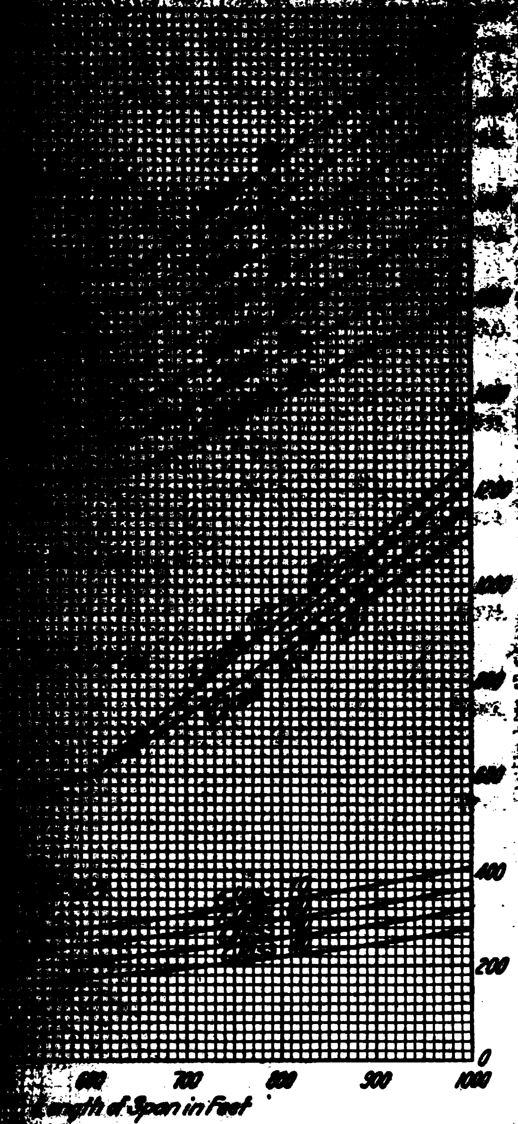


FIG. 55bb. Double-track-railway, Through, Pin-connected, Pratt-
Metal in Span.

ion that the rules previously given for finding the metal
track swings will apply also to the finding of those for doub
or, at any rate, the error involved by so doing would be
a comparative design made lately in the author's office
rim-bearing swing-span for the Pacific Highway Bridge
bia River between Vancouver, Wash., and Portland, O
structure being about fifty feet, the percentage for met
chinery, and on piers was thirty-five and a half, which



rough, Pin-connected, Petit-truss Spans—Metal
Laterals, and on Piers.

of metal per lineal foot of span for both
swings (either rim-bearing or centre bear-
diagrammed weights of similar fixed-span
and total span-length by ascertaining from

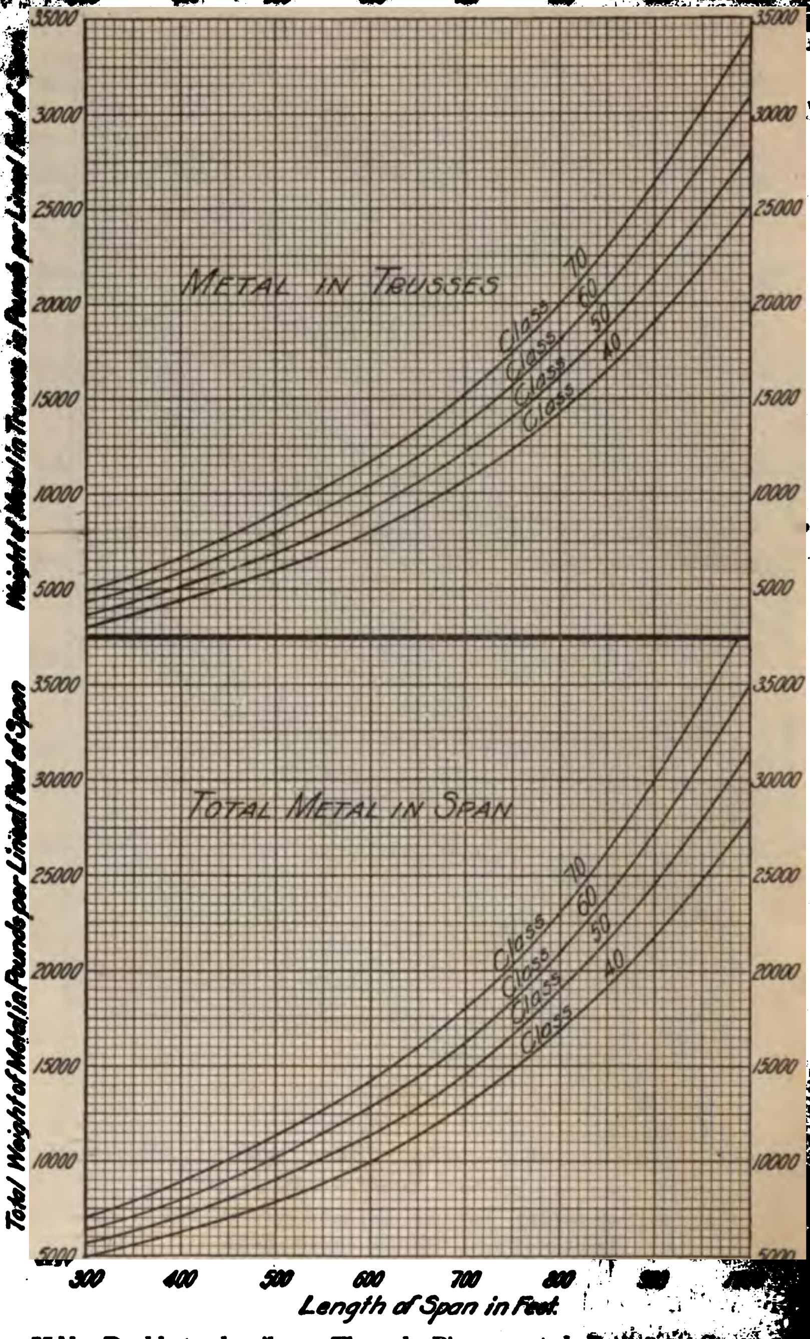
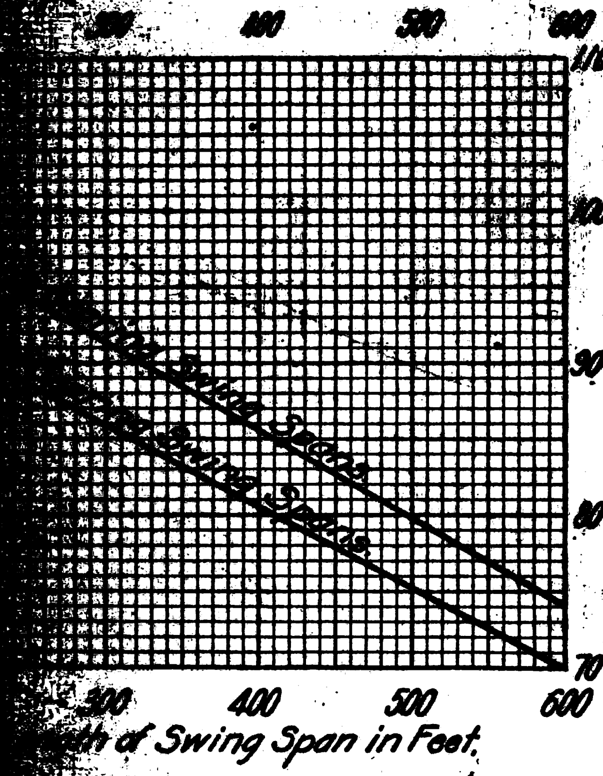


FIG. 55*dd*. Double-track-railway, Through, Pin-connected, Petit-truss Spans [illegible] in Trusses and Total Metal in Span.

apply to the [illegible] weights of [illegible]

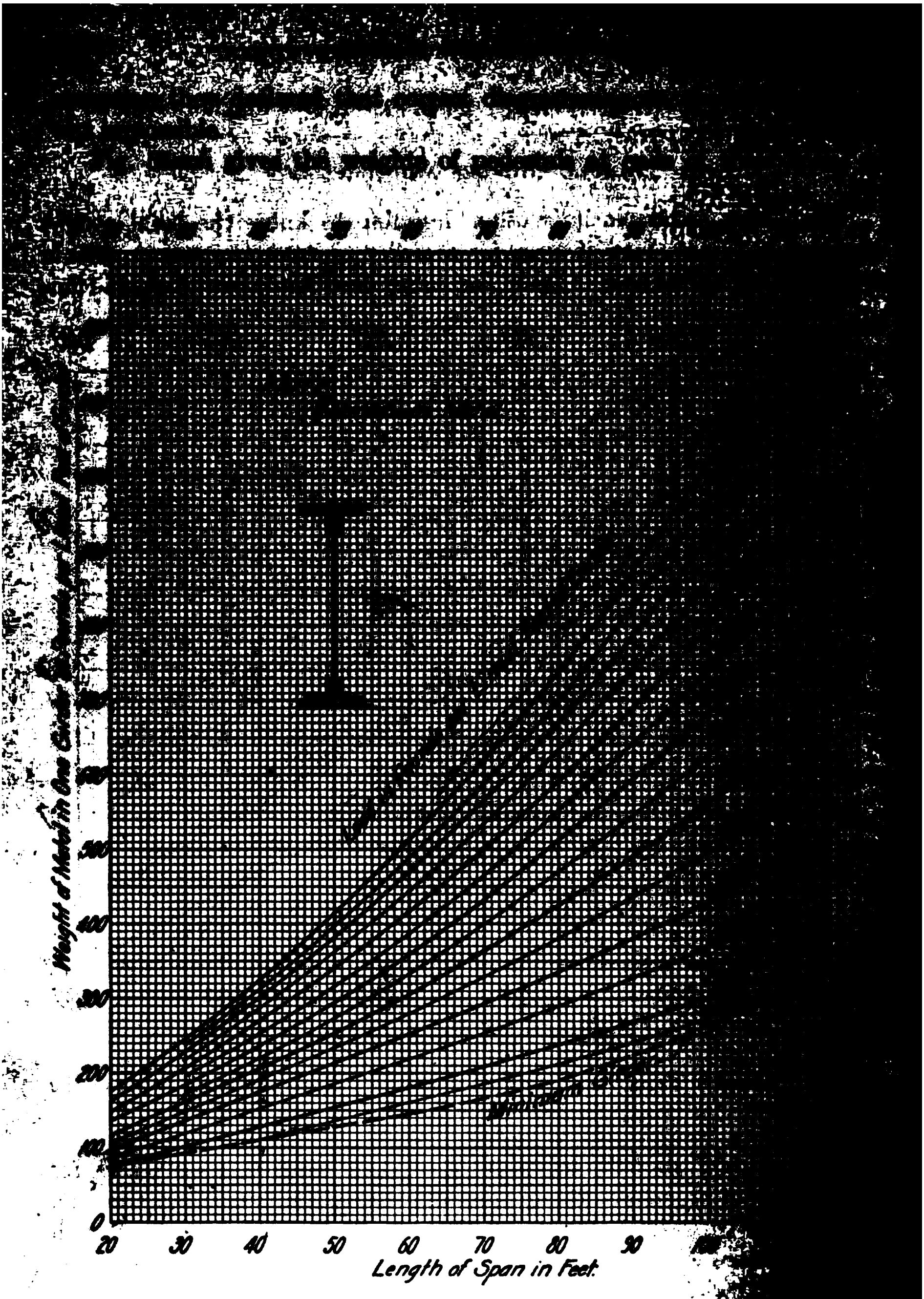
Girders and Trusses

often desirable to know the total weight
for a girder or truss to carry a certain
span, including dead load, live load, and im-



in Percentages of Weights of Simple Spans of the
Same Total Length.

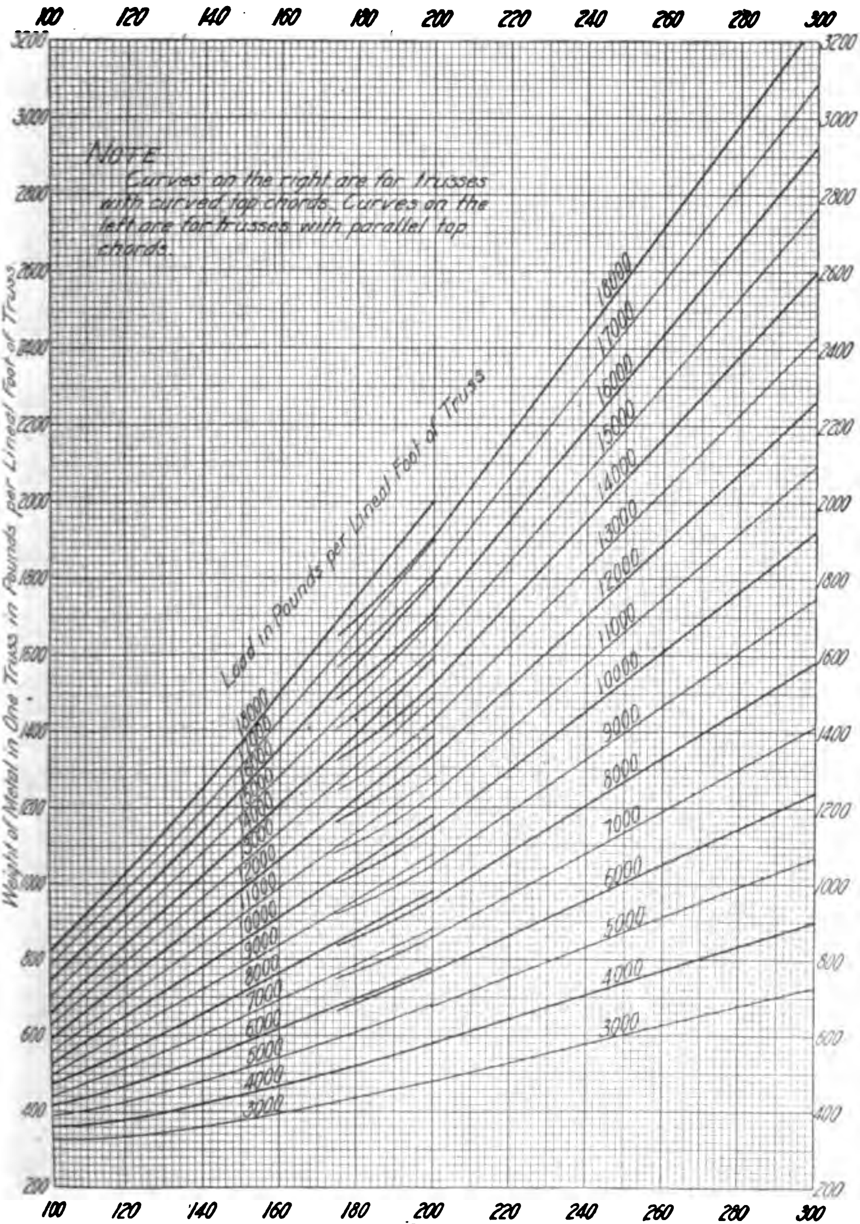
inclusive, give such weights respectively for
; through, riveted Pratt-trusses; through,
riveted Pratt-trusses; light, riveted, through
thickness of metal equal to five-sixteenths
pin-connected Pratt-trusses; and through,
These curves are self-explanatory. The
the weight of the girder or truss in every
employing diagrams similar to the seven
years, and has found them exceedingly use-
standing the predictions of his assistant
the task of their preparation; for without



NOTE.—The weight of the girder is to be included in finding the

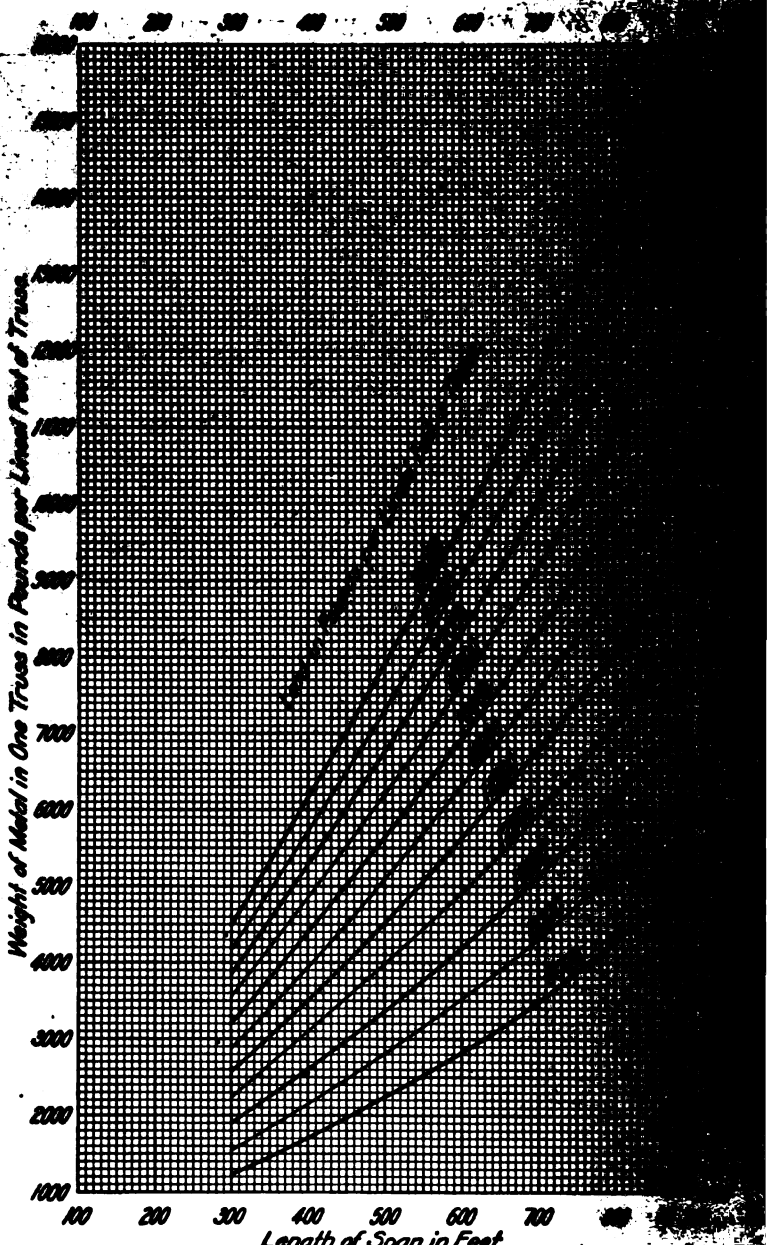
FIG. 55*ff*. Plate Girders with Riveted End-connections—Metal

total loads at corners, varying from small amounts up to corner. All shoes are of cast steel; and the weights pedestal pins and nuts.



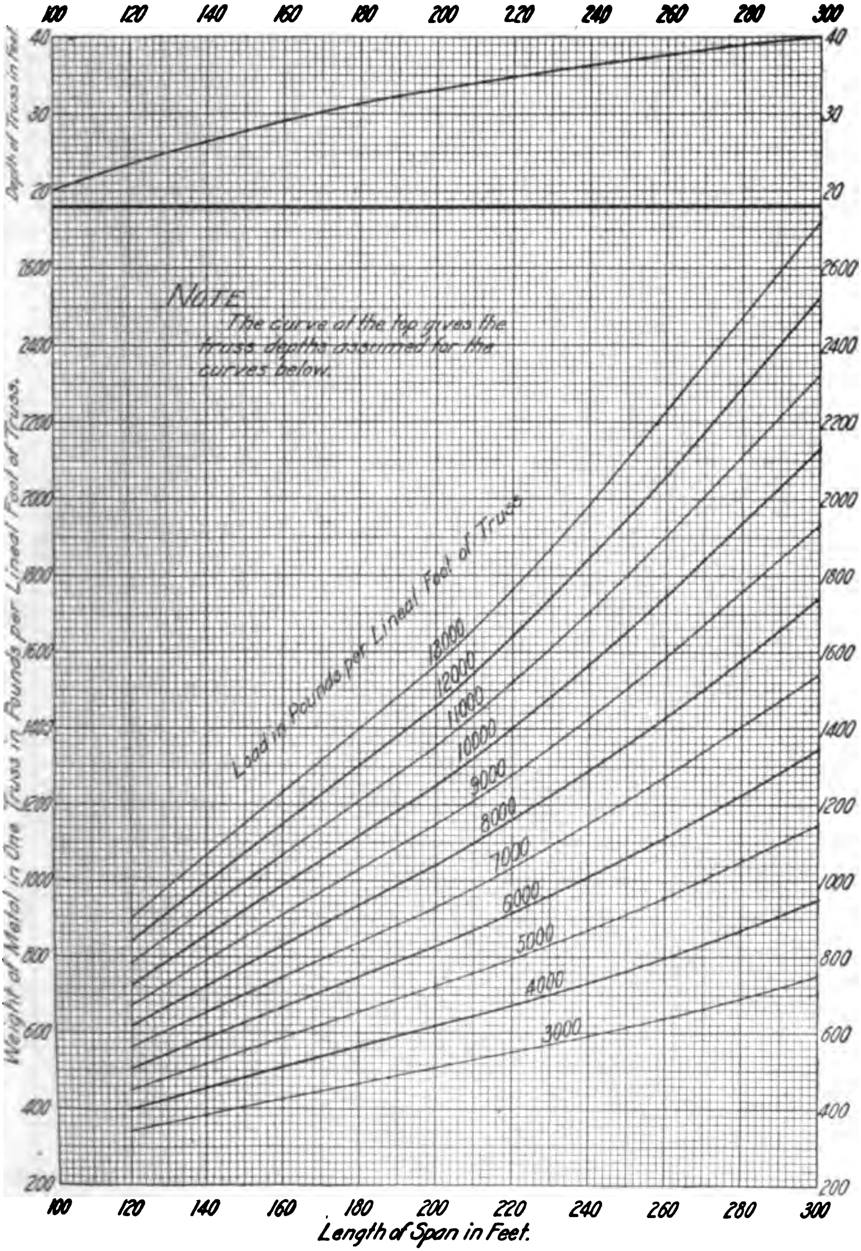
NOTE.—The weight of the truss is to be included in finding the load on the truss.

FIG. 55*gg*. Through, Riveted Pratt Trusses—Metal in One Truss.



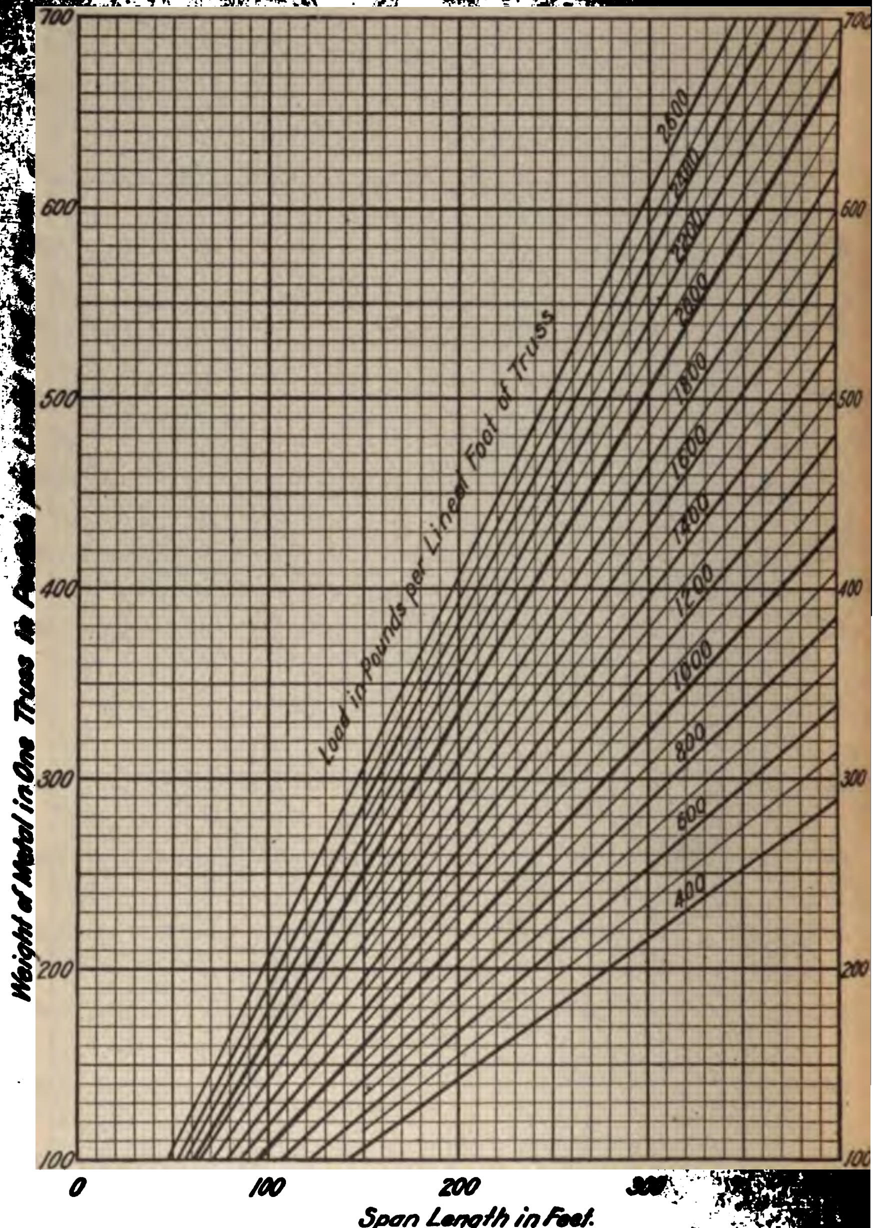
NOTE.—The weight of the truss is to be included in finding the [illegible]

FIG. 55*hh*. Through, Riveted Petit Trusses—Metal in [illegible]



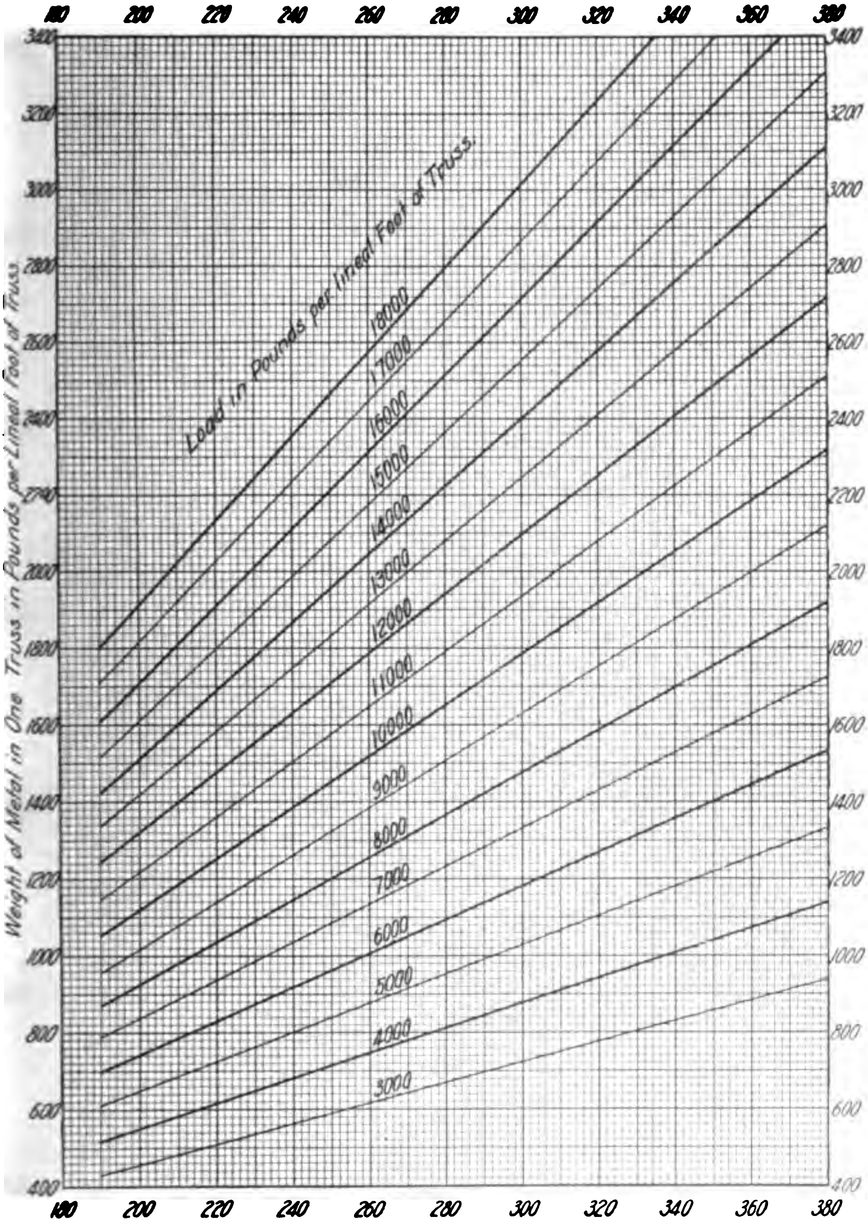
NOTE.—The weight of the truss is to be included in finding the load on the truss.

FIG. 55*ii*. Deck, Riveted Pratt Trusses—Metal in One Truss.



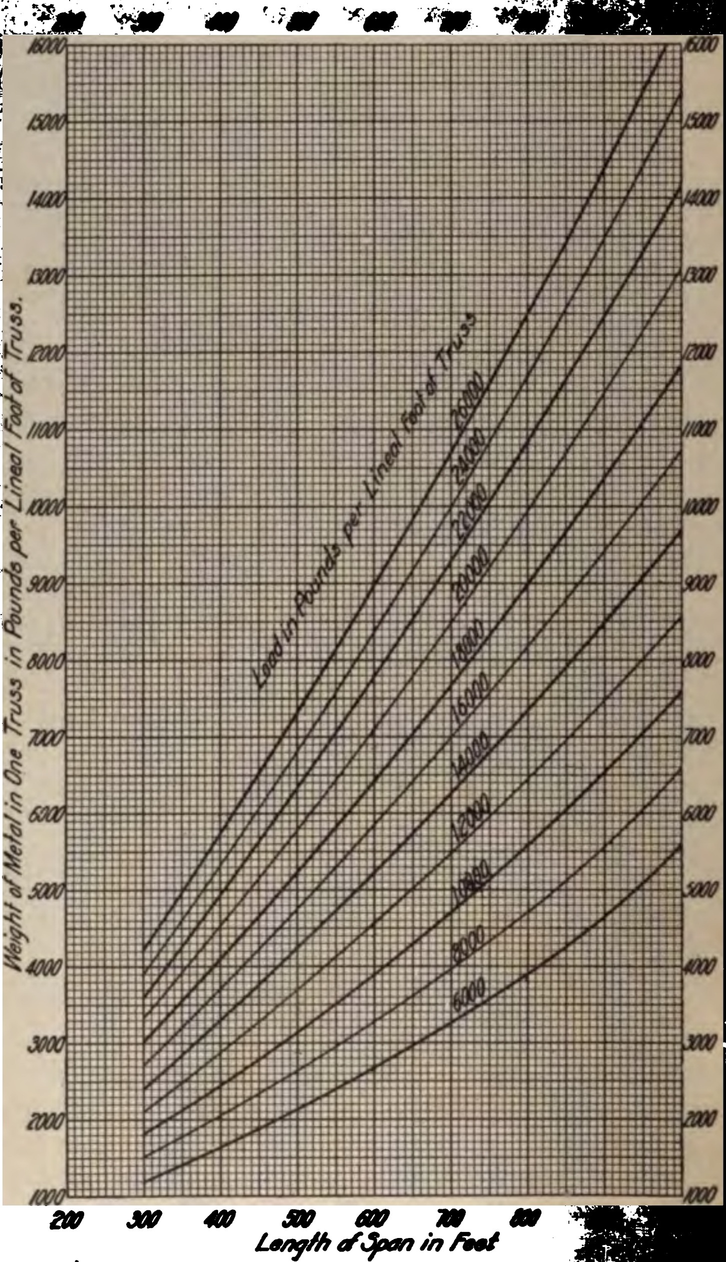
NOTE.—The weight of the truss is to be included in finding the

FIG. 55jj. Light, Through, Riveted, Highway Trusses—Metal



NOTE.—The weight of the truss is to be included in finding the load on the truss.

FIG. 55*kk*. Through Pin-connected Pratt Trusses—Metal in One Truss.

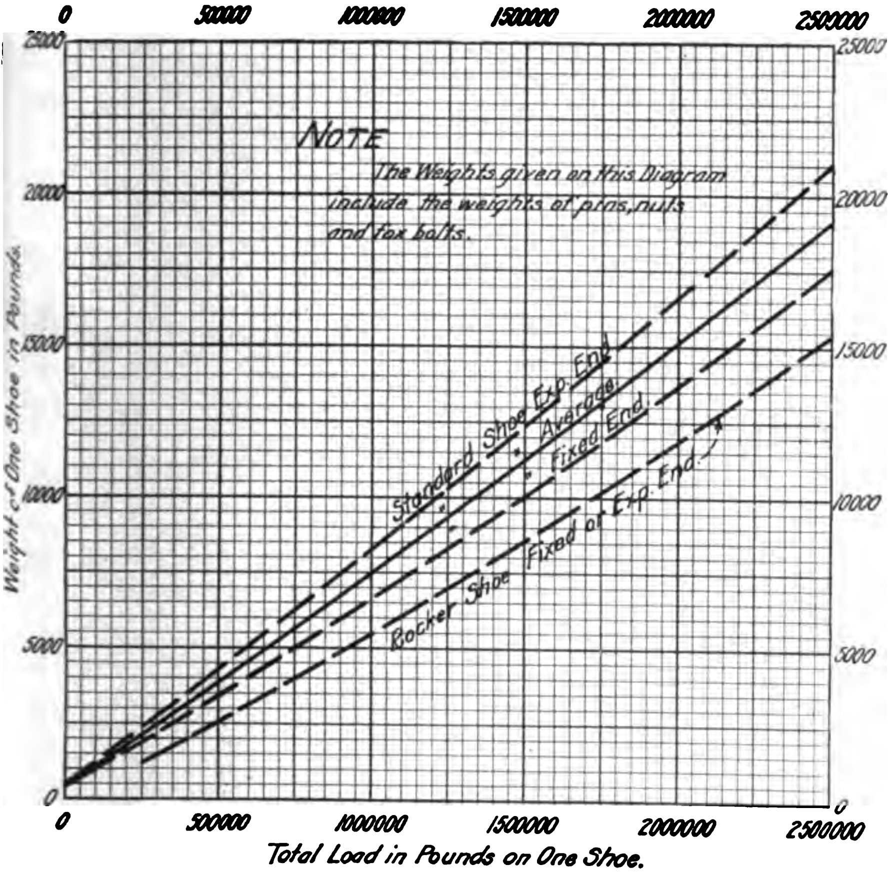


Note.—The weight of the truss is to be included in finding

FIG. 55*U*. Through, Pin-connected Petit Trusses—

SINGLE-TRACK RAILWAY TRESTLES—TYPE I

Figs. 55*nn* to 55*rr*, inclusive, show weights of metal for single-track, steam-railway, steel trestles with every alternate span a tower span, up to a limit of two hundred and forty (240) feet in height, measuring from top of masonry to base of rail.



NOTE
The Weights given on this Diagram include the weights of pins, nuts and fox bolts.

FIG. 55*mm*. Metal on Piers for Truss Spans.

Fig. 55*nn* gives the weights of metal per lineal foot of structure for the girders and girder bracing. (It is to be noted that there are no cover plates for the top flanges. They are omitted so as to avoid notching the ties to fit rivet heads.)

Fig. 55*oo* gives, for various heights from top of masonry to base of rail, the lengths of tower spans and of intermediate spans, and the distances from centre to centre of towers, the employment of which will make the weight of metal in the structure a minimum.

Fig. 55*pp* gives weight of metal for both the longitudinal and the

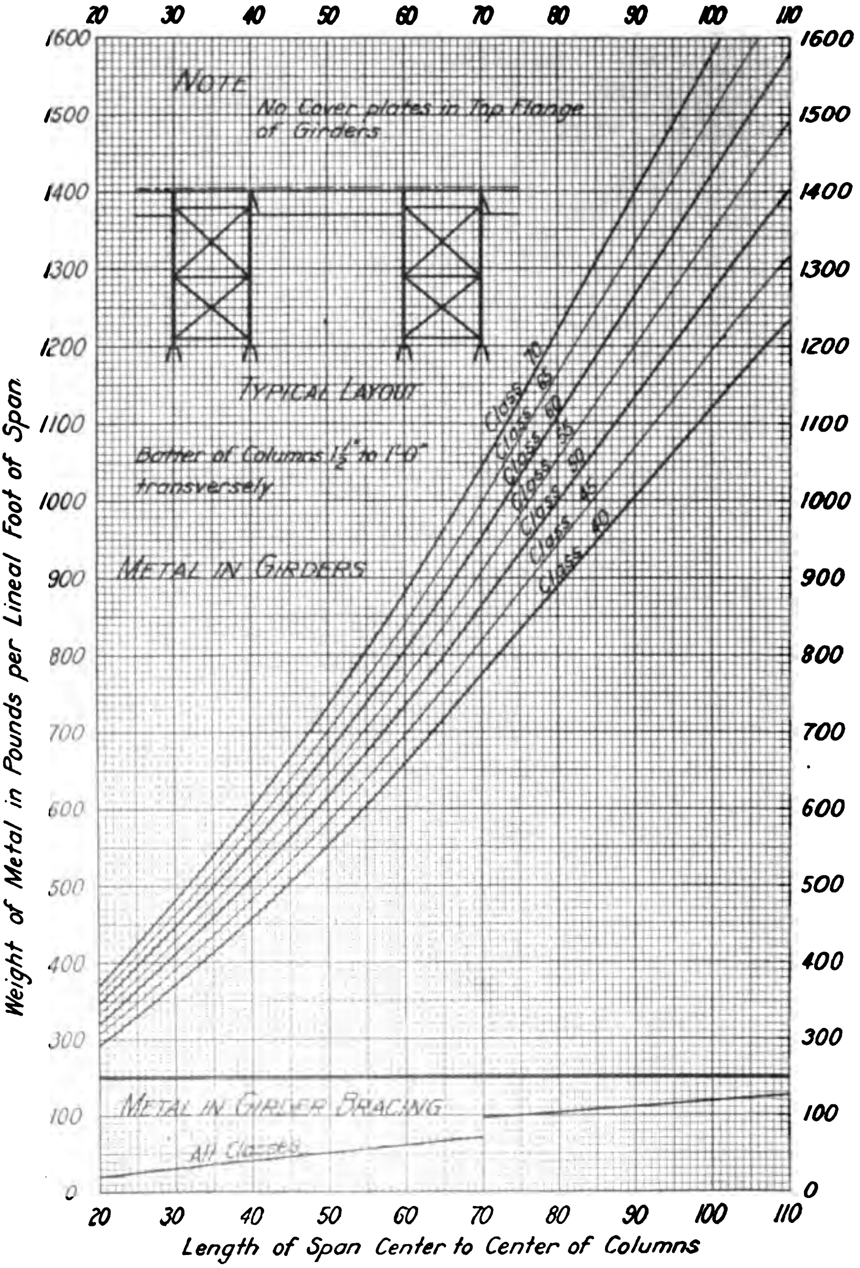


FIG. 55nn. Single-track-railway Trestles, Type I—Metal in Girders and Girder Bracing.

Type I—Economic Span Lengths.

transverse bracing of the towers. The curves
for various lengths of tower spans, and those of
heights of columns.

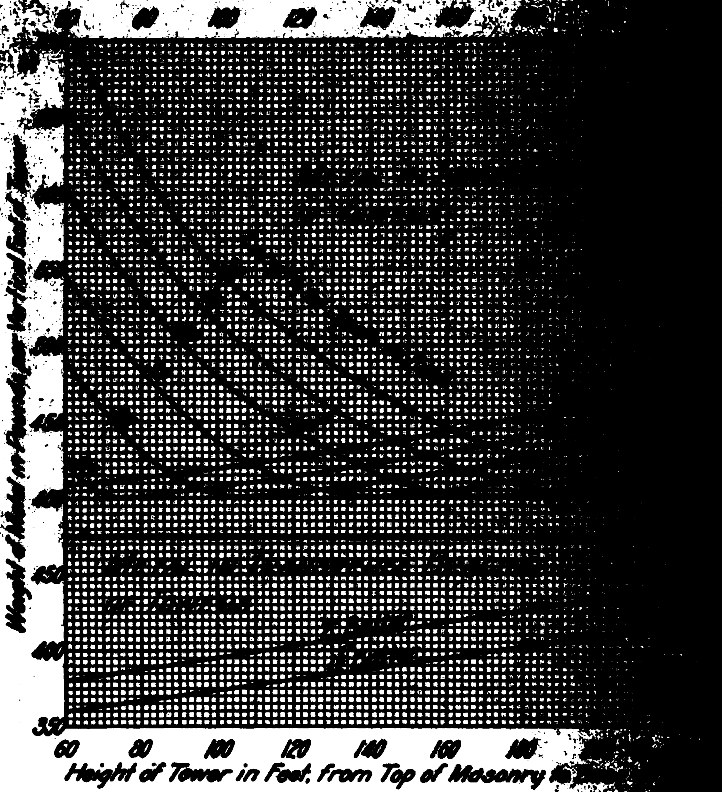


FIG. 55*pp*. Single-track Railway Trestles, Type I—Metal in L
Bracing of Towers.

Fig. 55*qq* indicates the weights of metal in the
tower. This is a "double tracing" diagram similar

Fig. 55*rr* shows, for various heights of trestle,
weight of metal per lineal foot of structure.

Fig. 55*ss* gives the approximate maximum loads
trestles of this type. It also is a "double tracing"

The above diagrams were figured upon the assump
tures were on tangent. For trestles on curves, the
are to be increased two per cent for each degree of curv

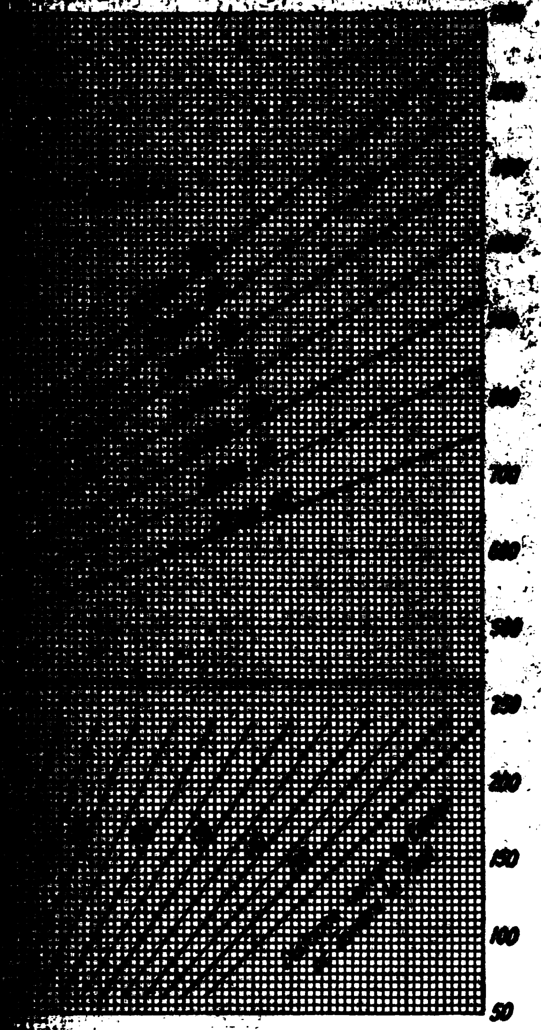
SINGLE-TRACK RAILWAY TRESTLES—TY

Figs. 55*tt* to 55*zz*, inclusive, give weights of meta
railway trestles for an assumed typical layout in whi

which there are two solitary bents, the

of metal in girders and girder

metal.



with height of tower and the distance centre upward to the curve for the live load.

Type I—Metal in Columns of Towers.

of metal per vertical foot in one bent;
metal per vertical foot in one tower.
g" diagrams.
, for various lengths oı interme-

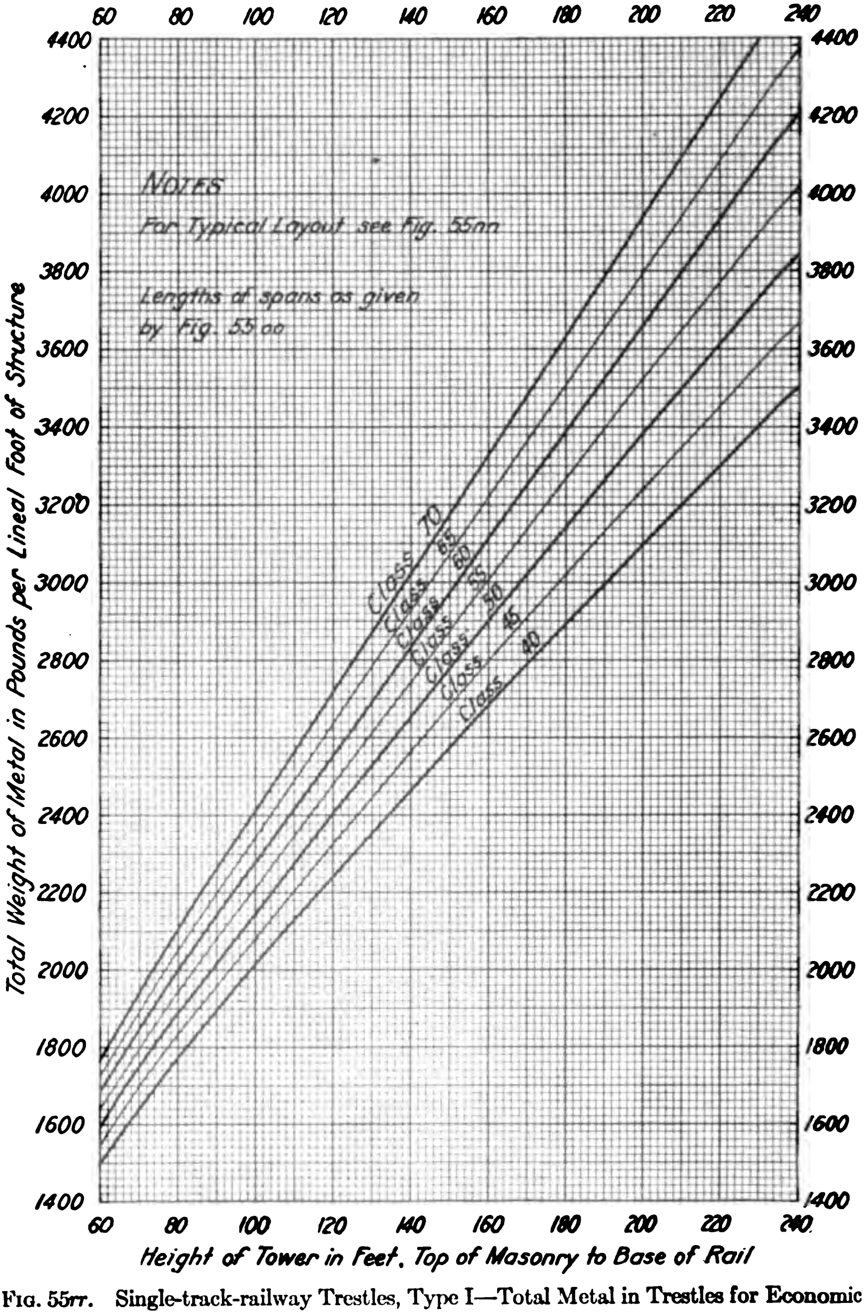


FIG. 55rr. Single-track-railway Trestles, Type I—Total Metal in Trestles for Economic Layouts.

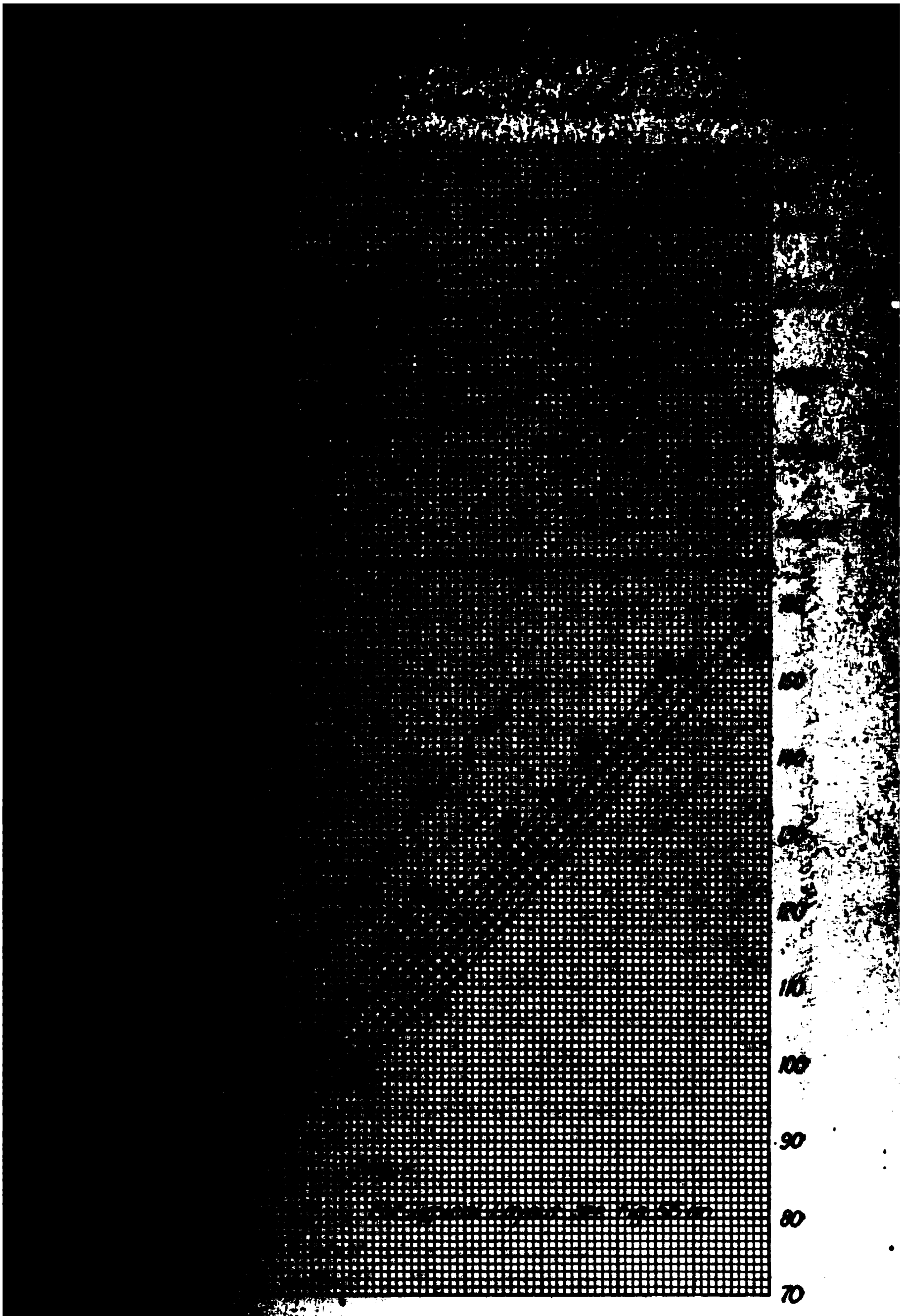


diagram with the height of tower and the distance vertically upward to the curve for the live load.

Trestles, Type I—Approximate Maximum Loads on Tops of Pedestals.

single spans, the weights of metal in bents and
structure. (It was found impossible to combine
"double tracing" diagram, as was done in Fig.
The approximate maximum loads on top of

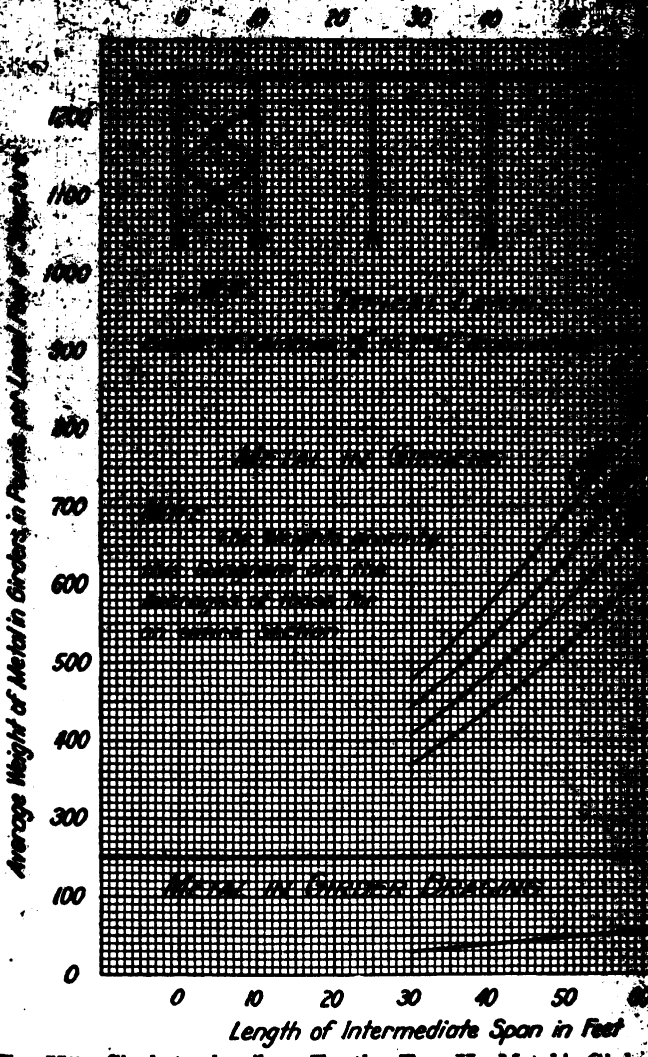


FIG. 55tt. Single-track-railway Trestles, Type II—Metal in Girders

Type II can be found from Fig. 55ss, which was prepared
trestles of Type I. For the pedestals under the towers,
to enter with the sum of the lengths of one tower span
diate span, instead of the distance from centre to centre
for the pedestals under the solitary bents, the sum of the
intermediate spans is to be used. For the tower

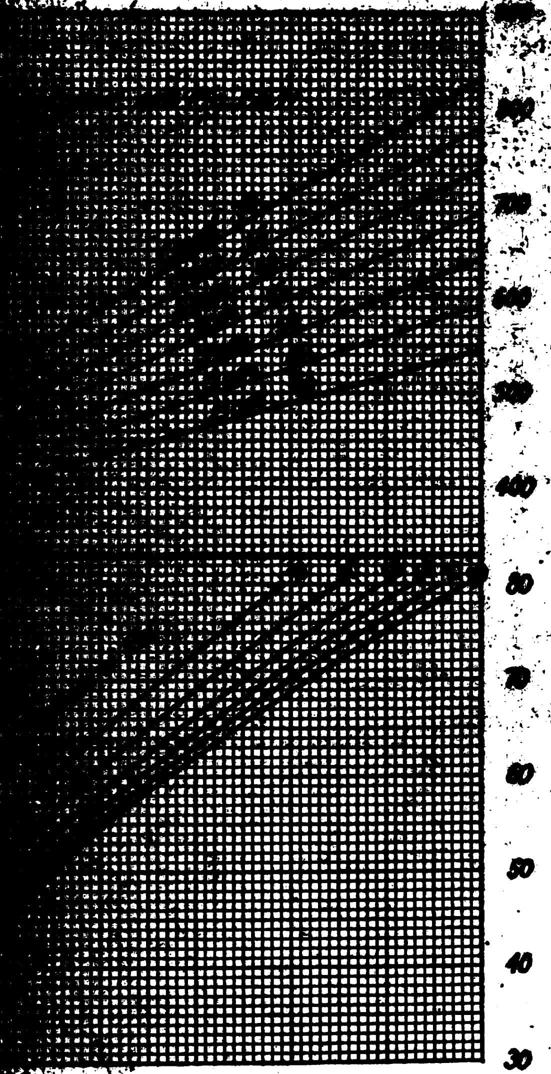


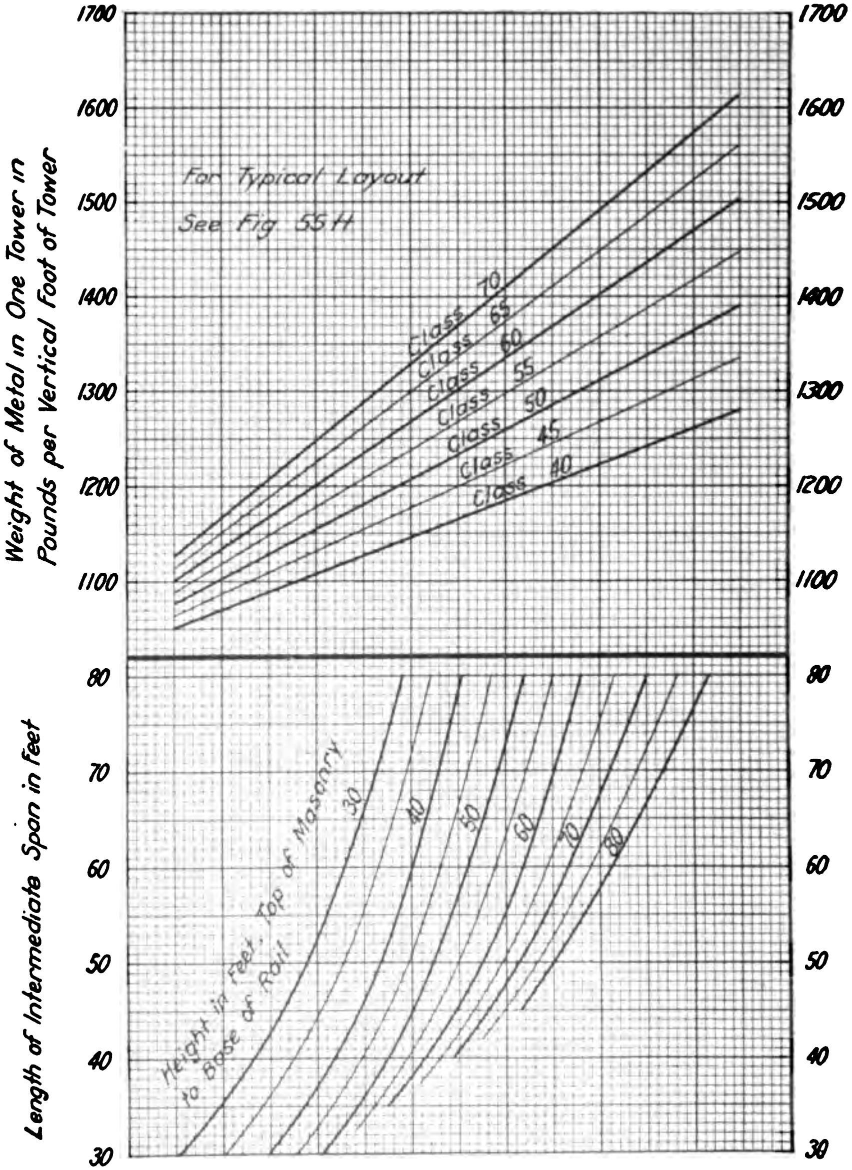
diagram with the height of tower and the length
upward to the curve for the live load.

Trestles, Type II—Metal in One Bent.

weights given by the above diagrams are
each degree of curvature, as in the case

DOUBLE-TRACK-RAILWAY TRESTLES

The author has never had occasion to extend systematically his researches so as to cover double-track-railway trestles, although, of course, he has designed and built structures of that kind. A rough approxima-



NOTE.—Enter lower portion of diagram with the height of tower and the length of intermediate span, and trace vertically upward to the curve for the live load.

FIG. 55*vv*. Single-track-railway Trestles, Type II—Metal in One Tower.

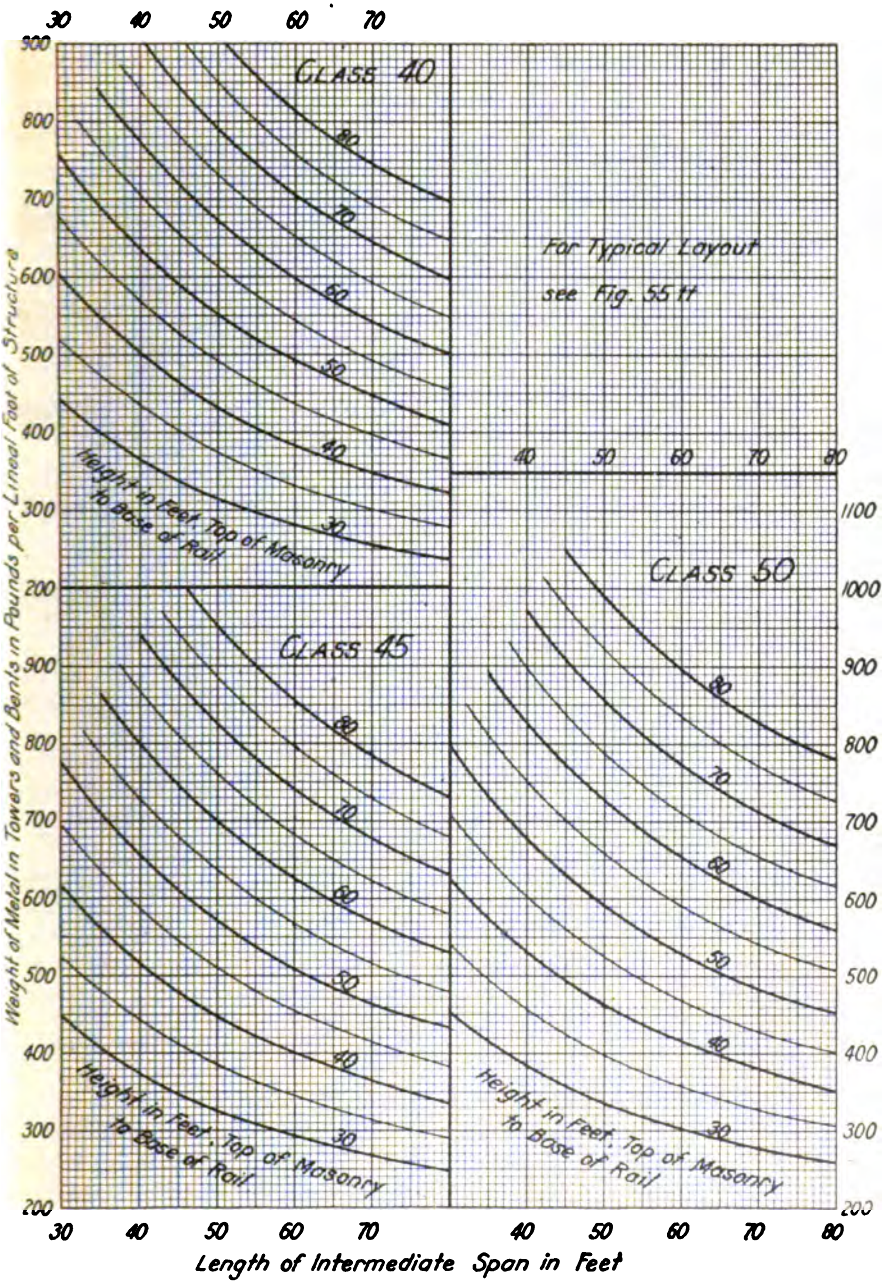


FIG. 55ww. Single-track-railway Trestles, Type II—Metal in Towers and Bents for Classes 40, 45, and 50.

tion for the weights thereof can be made from the preceding diagrams for single-track railway trestles as follows:

A. For weights of girders and girder bracing use twice those given for single-track trestles.

B. The weight of the longitudinal bracing in towers for double-track trestles can be taken as one and eight-tenths (1.8) times that for single-track trestles, because, although the thrust of train is twice as great, the weight does not increase directly as the traction stresses.

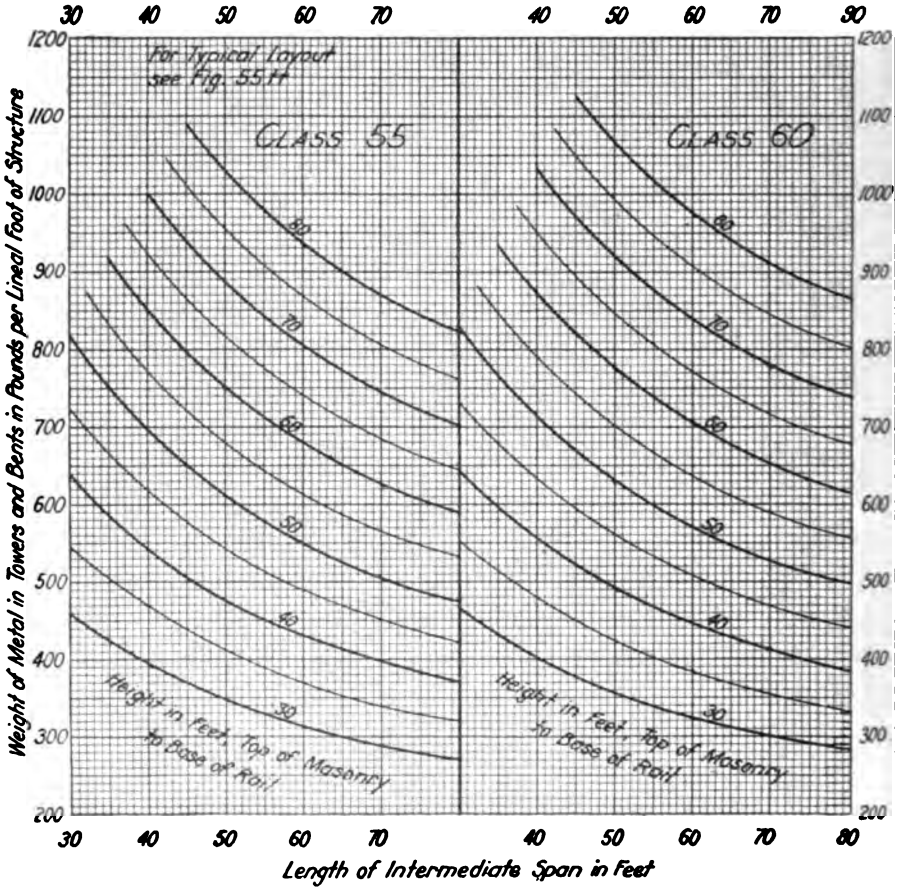


FIG. 55xx. Single-track-railway Trestles, Type II—Metal in Towers and Bents for Classes 55 and 60.

C. The weight of the transverse bracing in towers for a double-track trestle, including that of the cross-girders at top of bents, can be taken as one and seven-tenths (1.7) times as great as that for a single-track trestle.

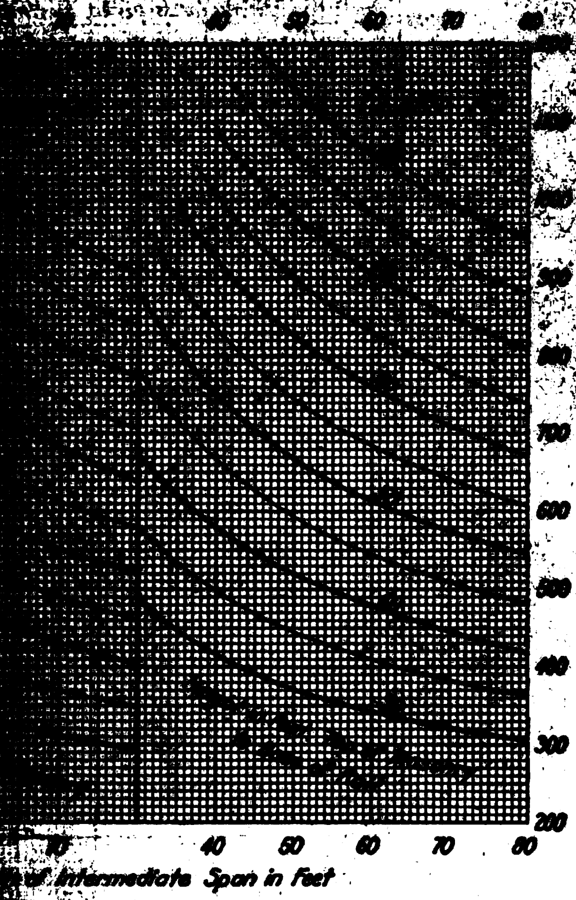
D. The weight of columns for a double-track trestle can be assumed as one and six-tenths (1.6) times that for a single-track trestle.

of metal in a double-track

ed, he must not forget that his figures

enough for a preliminary estimate only.

trestles on curves, the weights found in the



Trestles, Type II—Metal in Towers and Bents for Classes 65 and 70.

grams are to be increased two per cent for in the case of single-track trestles.

RAILWAY TRESTLES

nomic proportions for any single-track elec- quivalent uniform live load and the impact , eighty (80) feet should be computed, and sum of the corresponding live and impact ading should be figured. Call this ratio *r*.

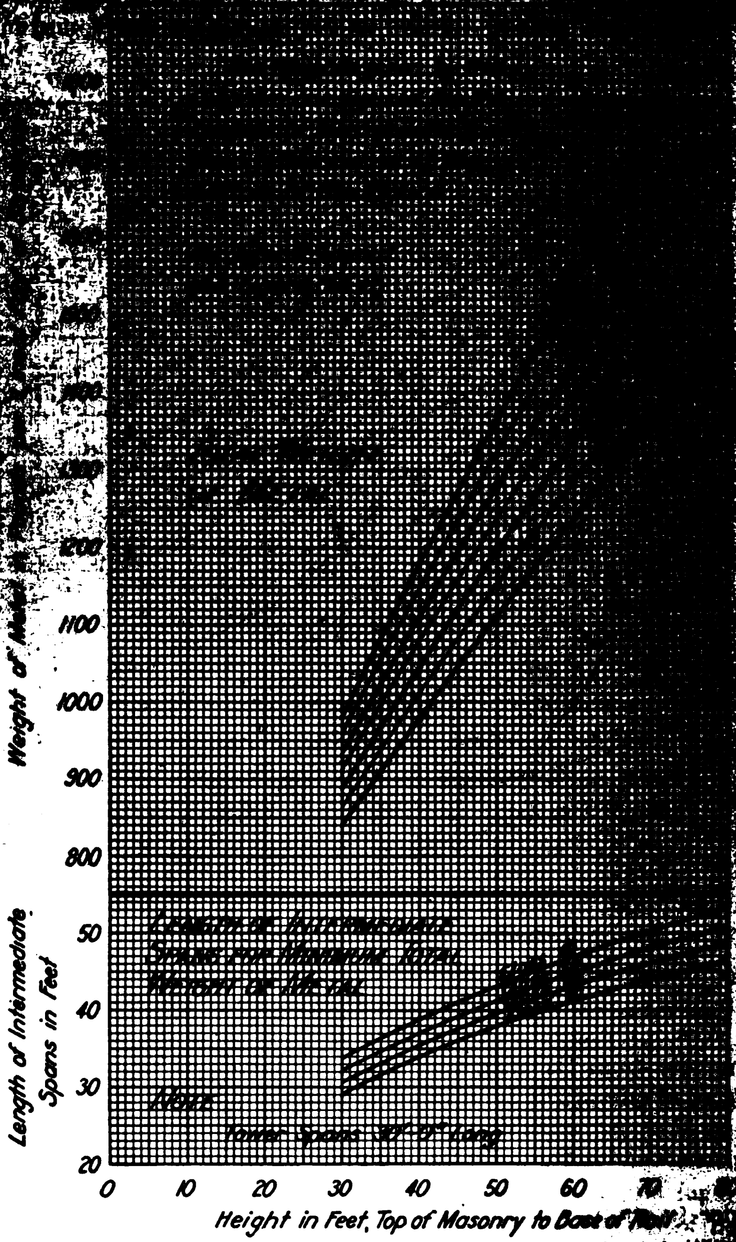


FIG. 55zz. Single-track-railway Trestles, Type II—Span Lengths [illegible] Trestles for Economic Layouts.

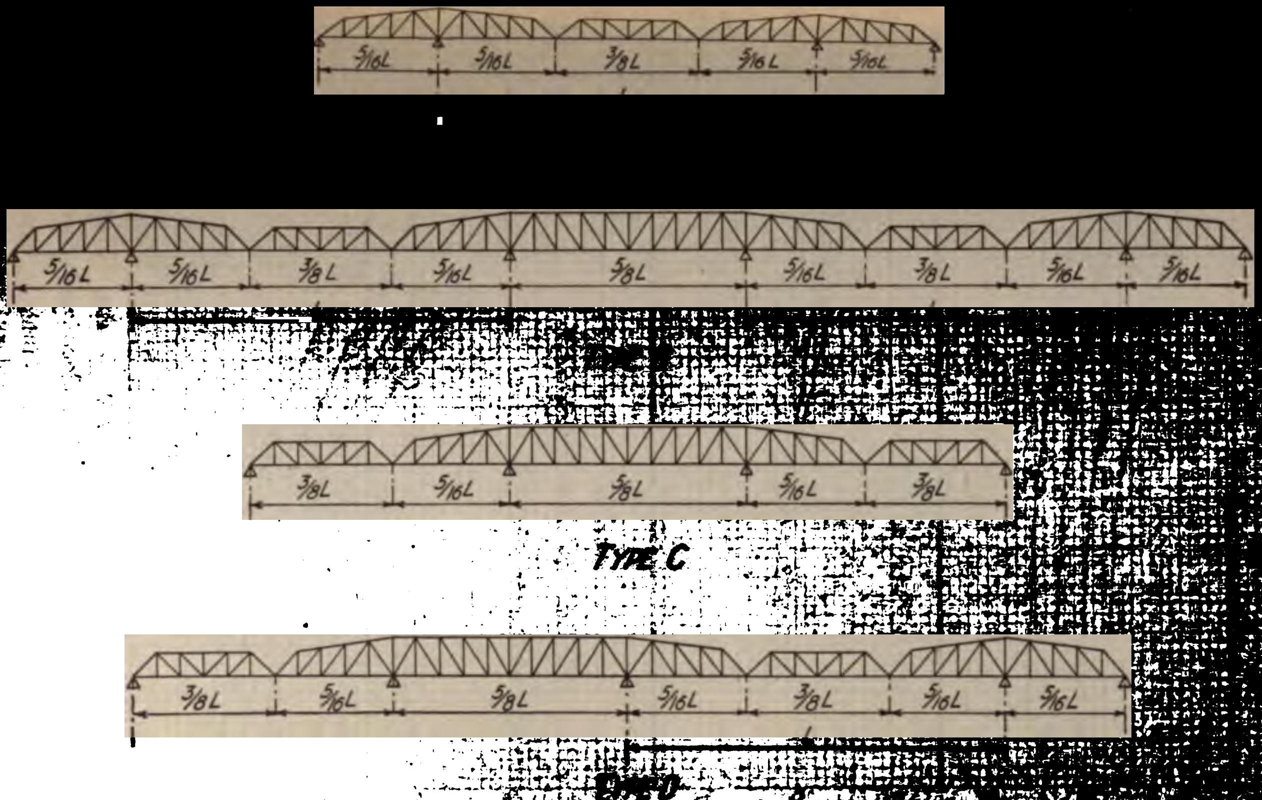


FIG. 55aaa. Typical Layouts for Double-track railway [illegible]

Fig. 55oo for a trestle of Type I, and from
The total loads per lineal foot of the girders

are then calculated, and their weights are determined from Fig. 55*ff*.

The weights of the girder bracing, of the longitudinal and transverse bracings of the towers, and of the transverse bracing of the bents will be about the same as in the case of a single-track-railway trestle, provided that $3/8''$ minimum thickness of metal be employed. If the use of $5/16''$ metal be permitted, the weights should be reduced twenty (20) per cent.

The weights of the columns can be found by the formula,

$$C_E = C_R \left(\frac{1+4r}{5}\right), \qquad \text{[Eq. 1]}$$

in which C_E = weight of columns for a single-track electric railway trestle,
C_R = weight of columns for single-track steam railway trestle, and
r = ratio of the live plus impact loads for the electric railway trestle to the live plus impact loads for the steam railway trestle, as above defined.

In case it be desired to apply the diagrams to a double-track electric railway trestle, it will be necessary first to figure the weights of metal for a single-track electric railway structure as just indicated, and then increase the weights of girders, of girder bracing, of transverse bracing in bents and towers, and of columns as previously explained for double-track railway trestles. The weight of the longitudinal bracing of the towers will be about the same as that for the single-track steam railway structure.

For electric railway trestles on curves, the weights found in the above manner are to be increased two per cent for each degree of curvature, as in the case of steam railway trestles.

The weights of electric railway trestles obtained as above are, of course, approximate only.

CANTILEVER BRIDGES

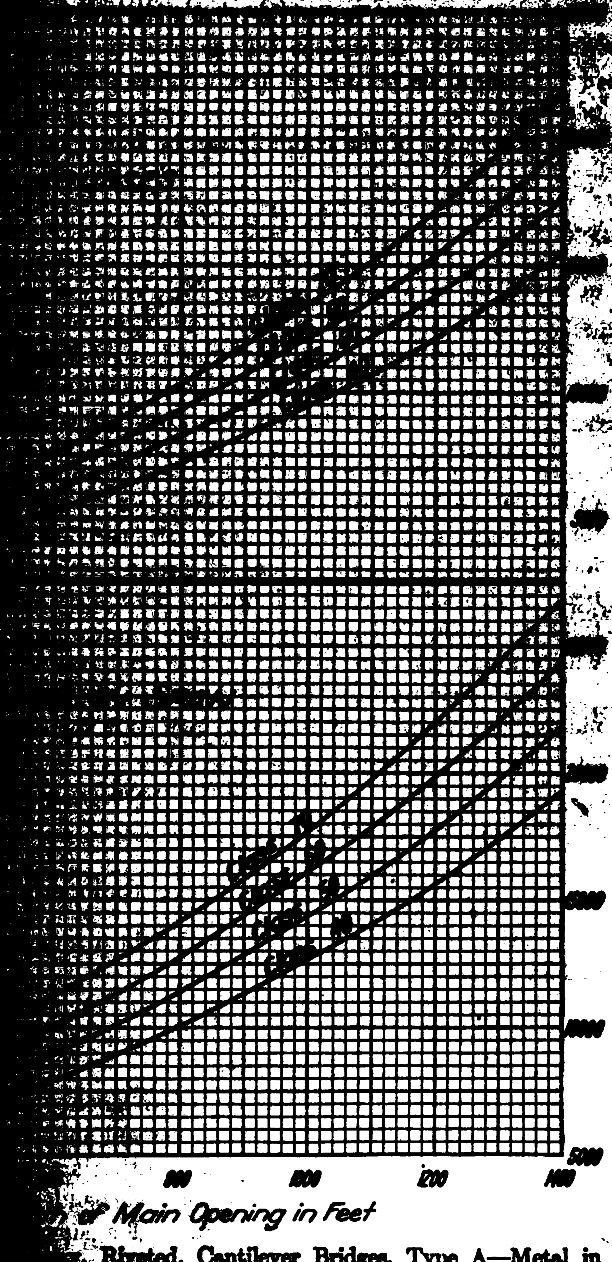
Cantilever bridges may be divided into four general types, as shown in Fig. 55*aaa*.

Type A consists consecutively of an anchor arm, a cantilever arm, a suspended span, a cantilever arm, and an anchor arm. This is the most commonly used of the four.

Type B consists consecutively of an anchor arm, a cantilever arm, a suspended span, a cantilever arm, a central anchor span, a cantilever arm, a suspended span, a cantilever arm, and an anchor arm.

Type C consists consecutively of a suspended span, a cantilever arm, an anchor span, a cantilever arm, and a suspended span, each of the two suspended spans being hung at one end to a cantilever arm and supported by a pier at the other.

Type D consists consecutively of a suspended span, a cantilever arm,



…y, Riveted, Cantilever Bridges, Type A—Metal in …and Total Metal in Bridge.

an anchor span, a cantilever arm, a suspended span, a cantilever arm, and an anchor arm, being similar to Class C at one end and to Class B at the other.

For the purpose of plotting weights of metal the following ratios have been assumed, as indicated in Fig. 55*aaa*. They are as nearly as may be the economic ones. Calling L the length of main opening, or that of a suspended span and two cantilever arms, the length of the suspended span is $\frac{3}{8}L$, that of each cantilever arm and of each anchor arm is $\frac{5}{16}L$, and that of the anchor span is $\frac{5}{8}L$.

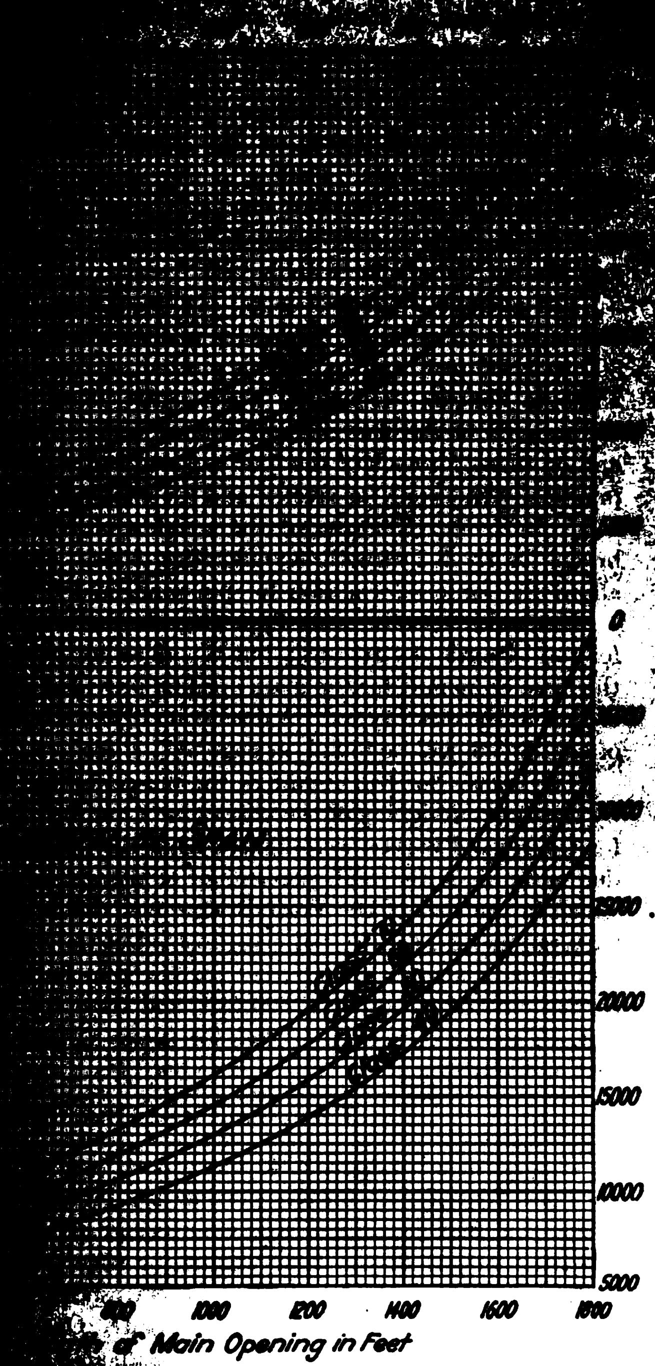
The average weights of metal per lineal foot *for total length of structure* have been carefully figured for main openings varying in length from 300 to 1,800 feet, and have been plotted on the diagrams shown in Figs. 55*bbb* to 55*mmm*, inclusive. Figs. 55*bbb*, 55*eee*, 55*hhh*, and 55*kkk* give the weights of the floor system, lateral system, and metal in anchorages and on piers, for each of the four types of cantilevers. These weights are practically the same for riveted and for pin-connected spans. Figs. 55*ccc*, 55*fff*, 55*iii*, and 55*lll* record the weights of trusses and total metal in bridge for riveted structures; and Figs. 55*ddd*, 55*ggg*, 55*jjj*, and 55*mmm*, afford the same information for pin-connected bridges.

It should be noted that Type C gives the least weight per lineal foot for total length of structure; but this does not necessarily mean that it is the most economic, for the main opening provided is only eleven-sixteenths of that in the other types. A discussion of the economics of the four types of cantilevers will be found on page 587, *et seq.*

The curves for the weight of the pin-connected trusses were obtained by the direct designing of the trusses for a number of span lengths. Those for the riveted trusses were figured from the pin-connected curves, taking due account of the high percentage of details in heavy riveted trusses, which in the case of the Fratt Bridge over the Missouri River at Kansas City ran as high as fifty per cent, instead of the usual thirty-five per cent for ordinary spans. The curves for the pin-connected spans have been carried out to a length of 1,800 feet, and those for riveted spans to 1,400 feet. The use of riveted trusses for spans as long as the latter limit is very unlikely.

TRANSFORMATION FORMULÆ

It is often advantageous to know how to obtain the weight of metal per lineal foot of span for any portion of a bridge when the corresponding weight for that portion of a similar bridge is known. For instance, if the truss weight or the floor weight for a certain bridge and a certain loading be given, what would be the corresponding weight for a similar bridge having a heavier or a lighter load? Or, if the truss weight per lineal foot of span for a certain live load and a certain span length be known, what would be the corresponding weight per foot for the same live load in a longer or a shorter span? Or, if the truss weight or the



way, Pin-connected, Cantilever Bridges, Type A—
and Total Metal in Bridge.

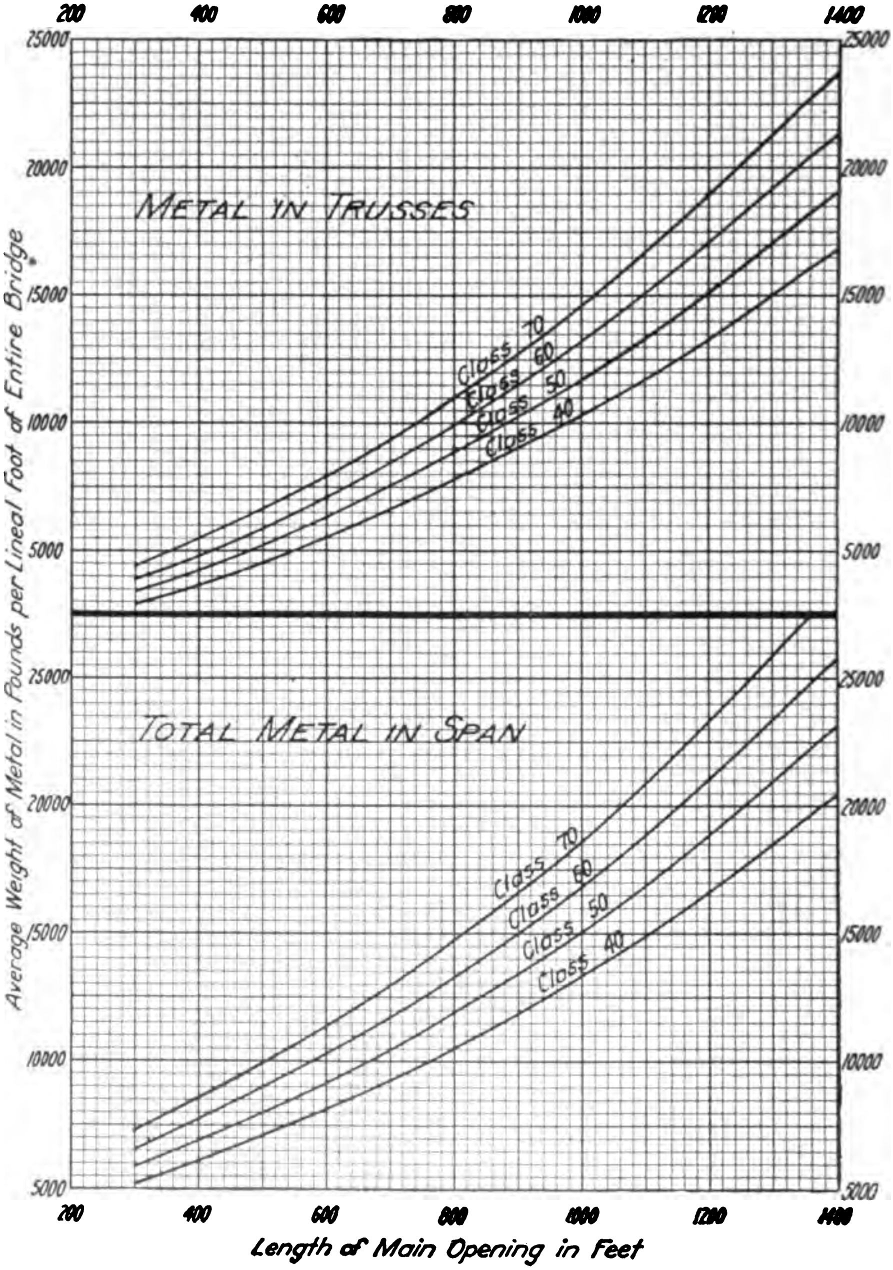


FIG. 55*fff*. Double-track-railway, Riveted, Cantilever Bridges, Type B—Metal in Trusses and Total Metal in Bridge.

y, Pin-connected, Cantilever Bridges, Type B—Metal
and Total Metal in Bridge.

floor weight per lineal foot of span for a carbon steel bridge be known, what would be the corresponding weight for a similar bridge manufactured from an alloy steel of a certain elastic limit?

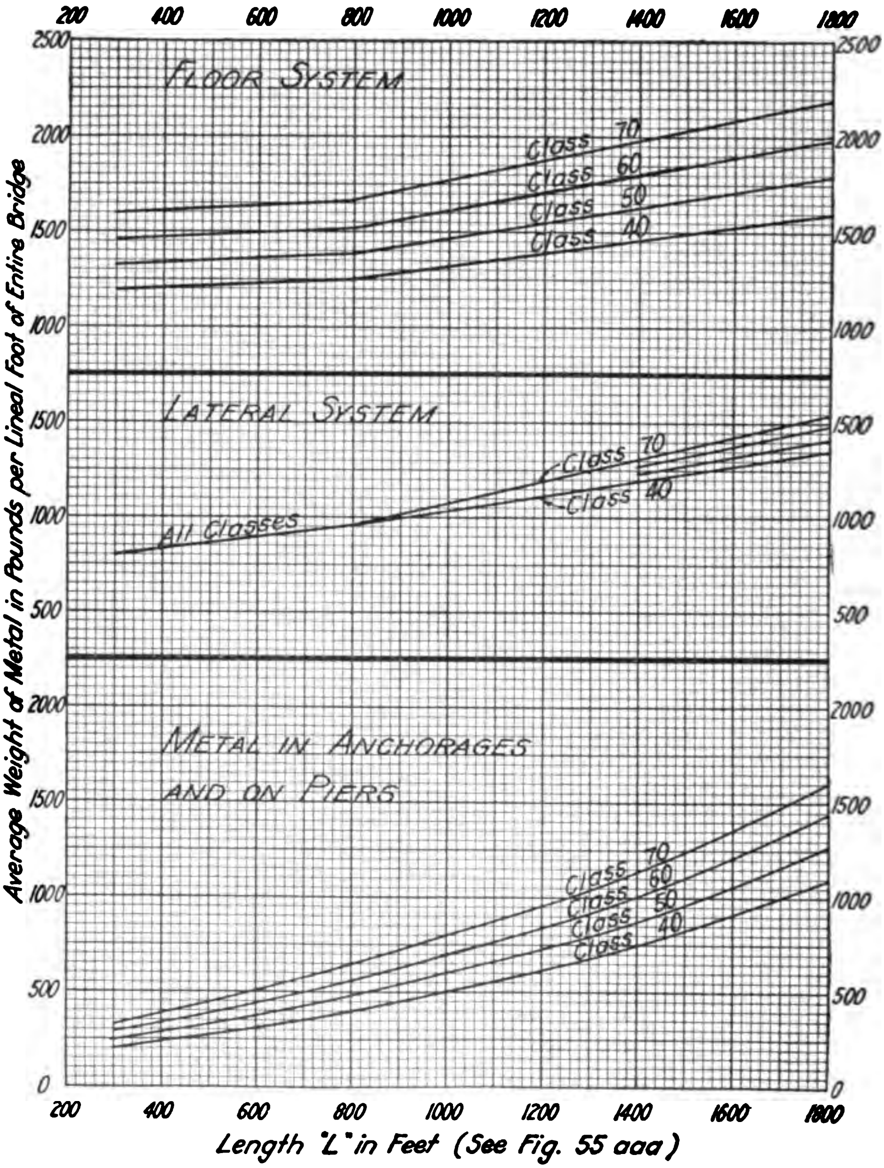
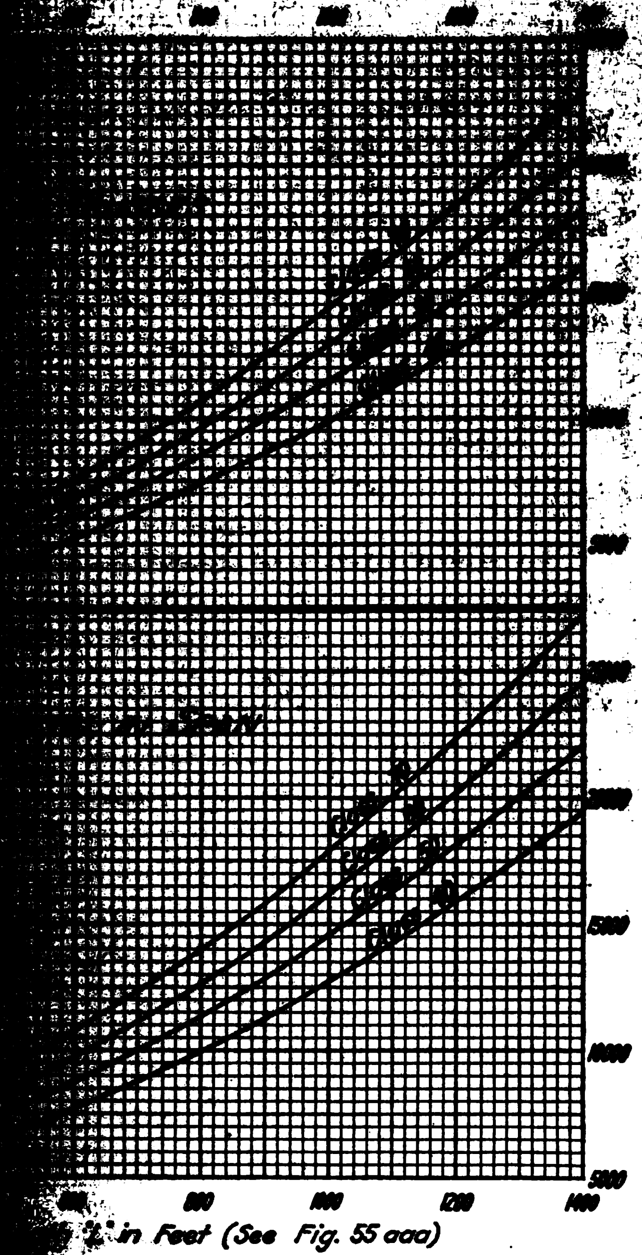


FIG. 55*hhh*. Double-track-railway, Cantilever Bridges, Type C—Metal in Floor System, Laterals, and on Piers.

For many years the author has studied deeply the theory of such weight variation and from time to time has given some of the results



Riveted, Cantilever Bridges, Type C—Metal in and Total Metal in Bridges.

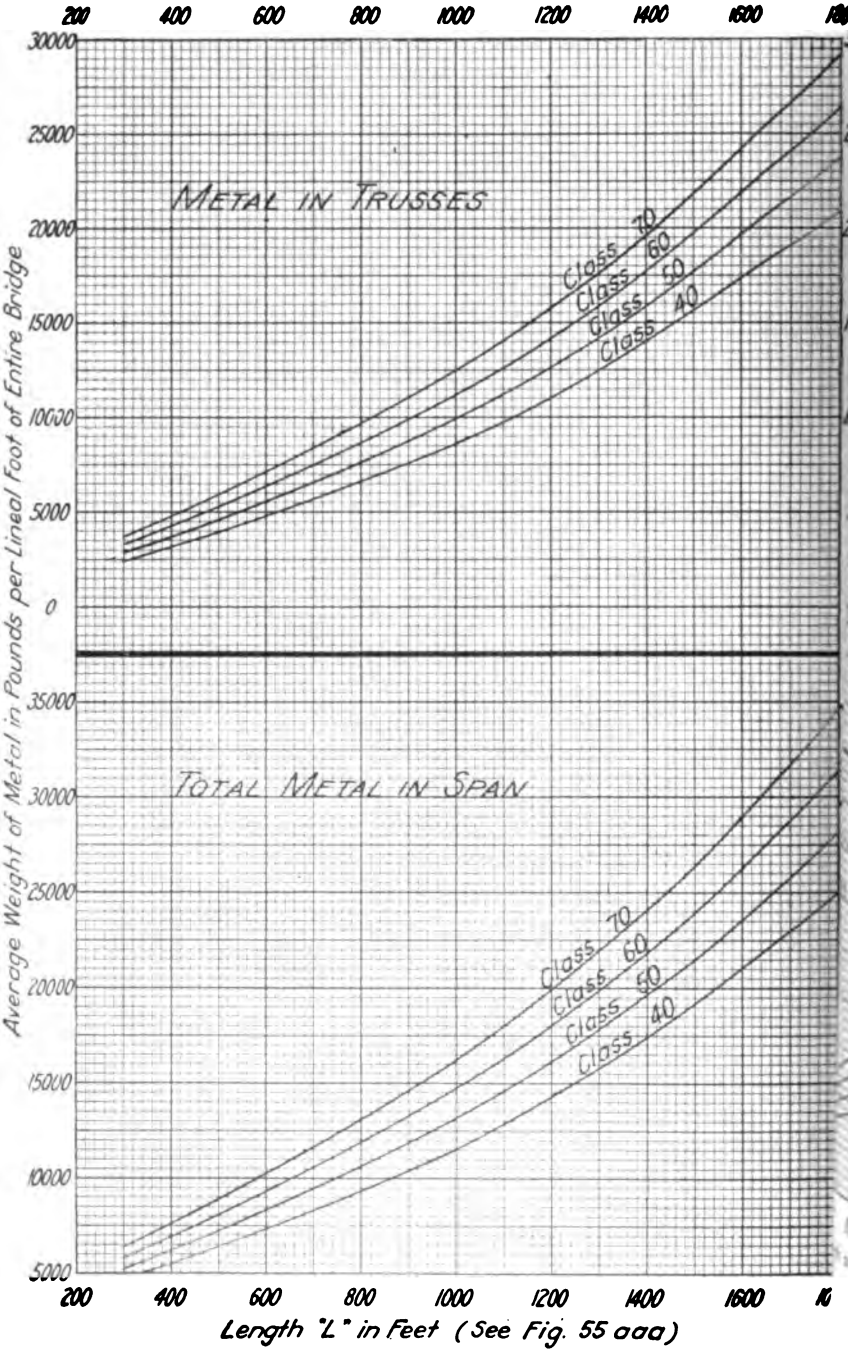
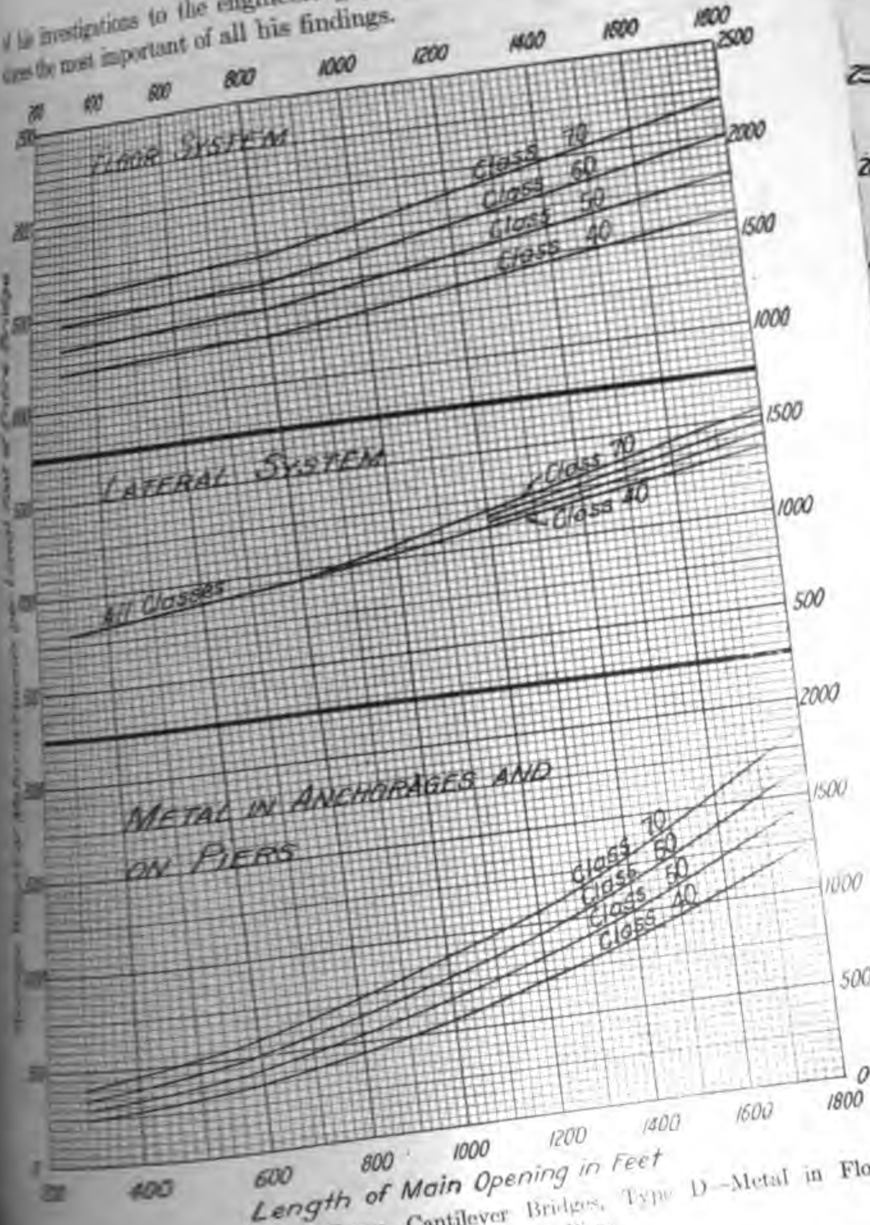


Fig. 555*jjj*. Double-track-railway, Pin-connected, Cantilever Bridges, Type C—Metal in Trusses and Total Metal in Bridge.

his investigations to the engineering profession. He herewith reproduces the most important of all his findings.



[illegible] Double-track-railway, Cantilever Bridges, Type D—Metal in Floor System, Laterals, and on Piers.

To ascertain the weight per foot B' of the lateral system in a span length l' from the corresponding known weight B in a span of length l, following approximate formula may be used, provided the width of superstructure remain unchanged:

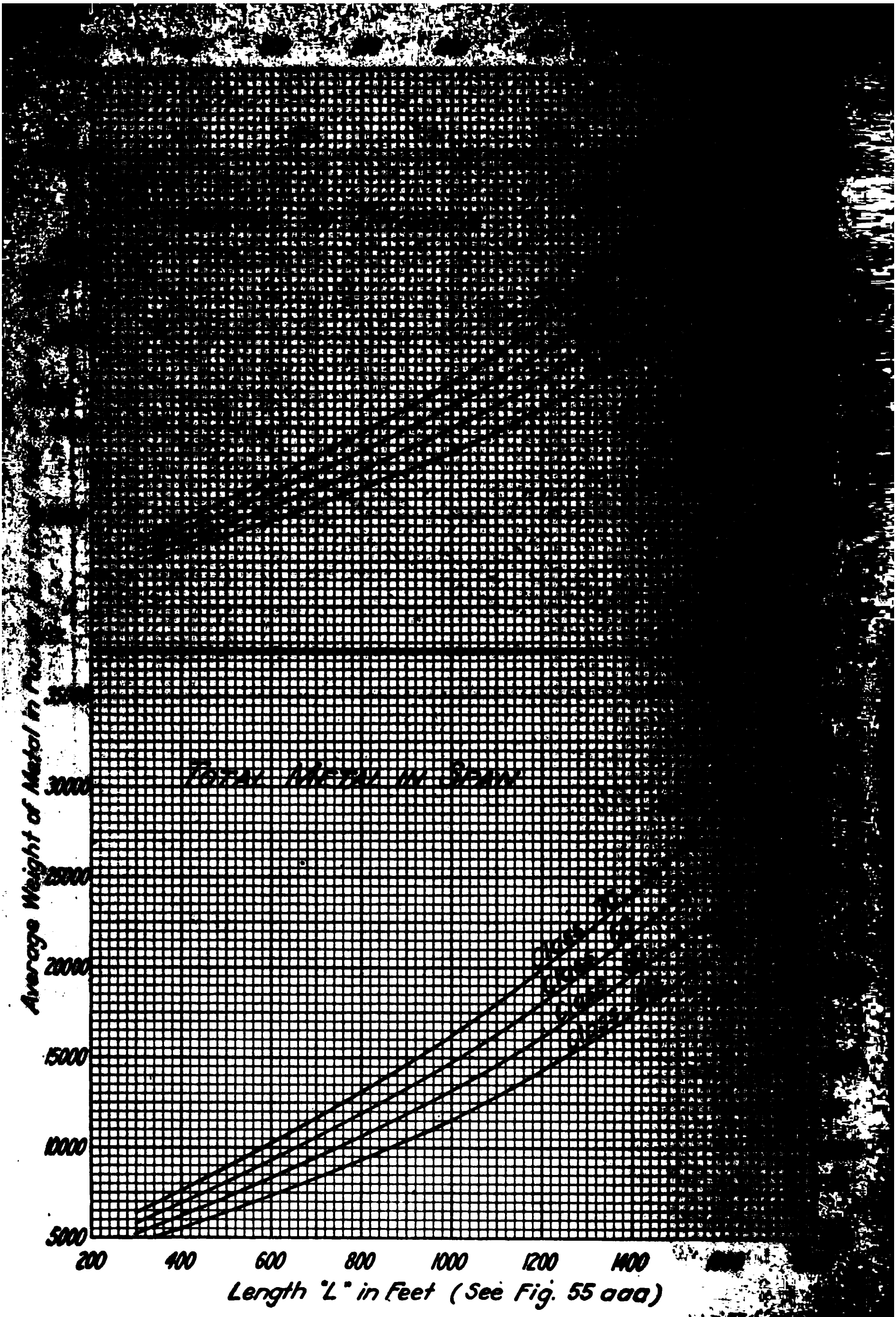


FIG. 555*jjj*. Double-track-railway, Pin-connected, Cantilever Bri
Metal in Trusses and Total Metal in Bridge.

ay, Cantilever Bridges, Type D—Metal in Floor
Laterals, and on Piers.

per foot B' of the lateral system in a span
onding known weight B in a span of length l,
formula may be used, provided the width of
unchanged:

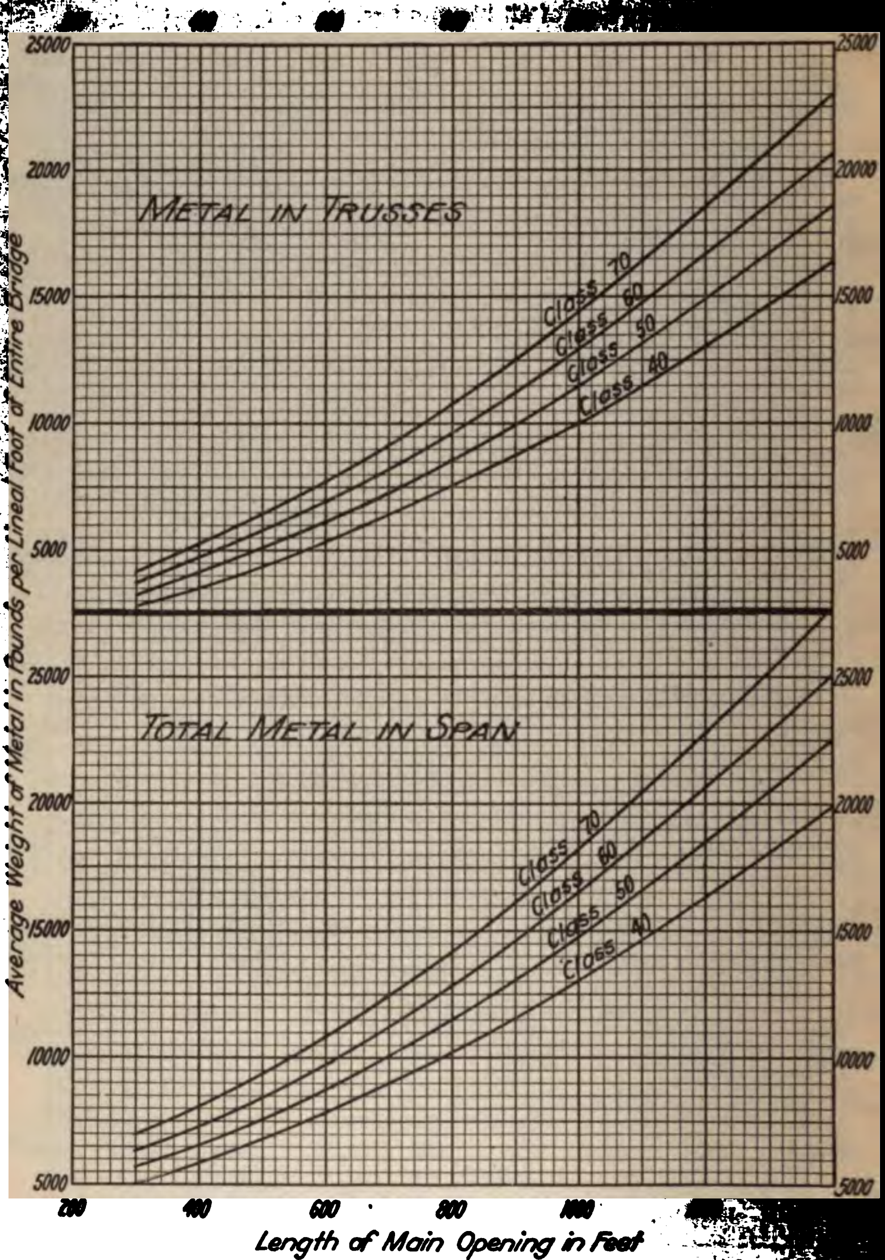


FIG. 55*III*. Double-track-railway, Riveted, Cantilever Bridges, Type [illegible] Trusses and Total Metal in Bridge.

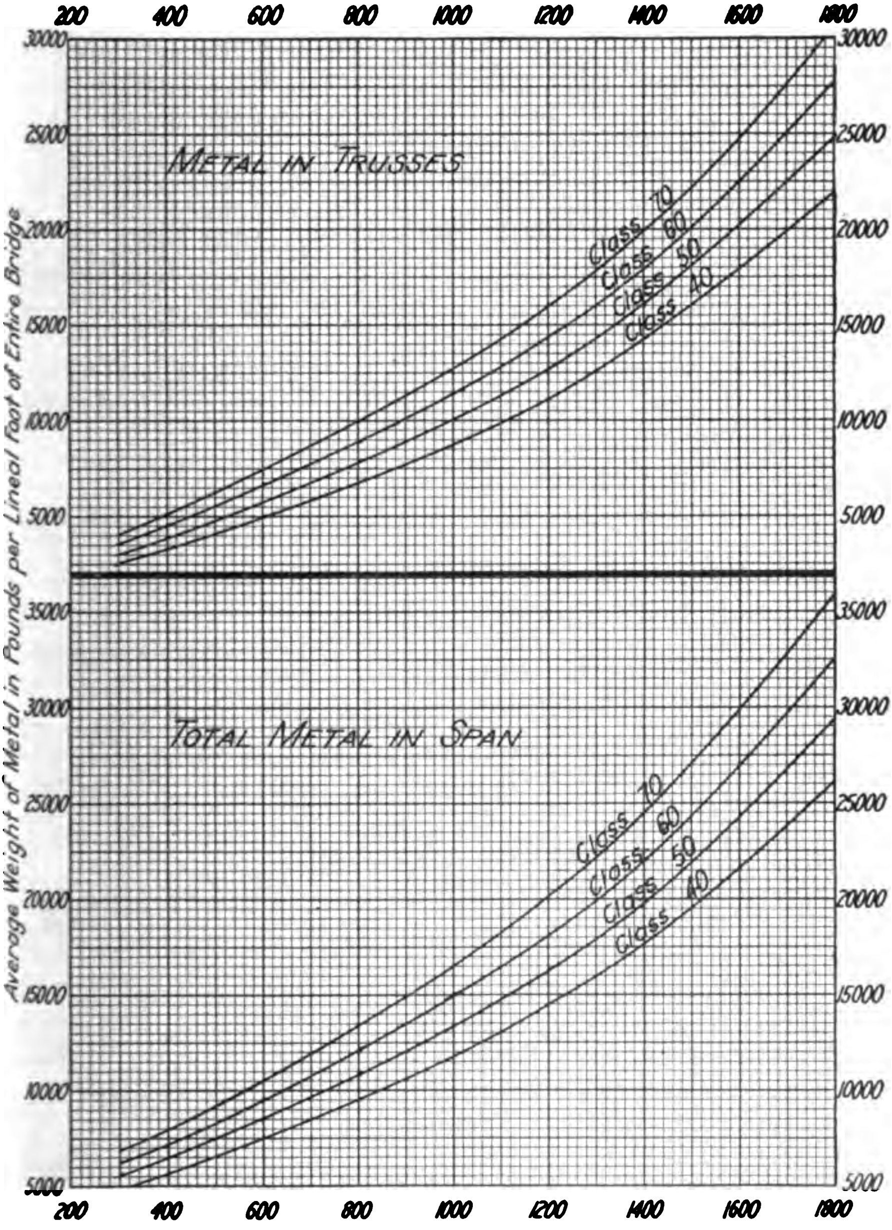


Fig. 55*mmm*. Double-track-railway, Pin-connected, Cantilever Bridges, Type D—Metal in Trusses and Total Metal in Bridge.

[illegible]

[illegible] the assumption [illegible] the width [illegible] absolutely [illegible] almost exactly true [illegible] in length and for double-track spans [illegible] it applies fairly well also to single-track spans [illegible] and when the modification above mentioned [illegible] distance between central planes of trusses is duly [illegible]

To find the weight of floor system F' for an [illegible] load per lineal foot w' from the weight F for a corre[illegible] following approximate formula may be used:

$$F' = F\left(a + (1 - a)\frac{w'}{w}\right),$$

where a is 0.6 for single-track bridges and 0.5 for [illegible] Theoretically it would have been more logical to let the [illegible] w' represent the sums of live load, impact, and dead [illegible] have reduced the values of a; but it saves time to use [illegible] finding the ratio of reduction. Letting the ratio $\frac{w'}{w} = r$, [illegible] single-track bridges will be

$$F' = F(0.6 + 0.4r);$$

and that for double-track bridges will be

$$F' = F(0.5 + 0.5r).$$

To find the truss weight T' per lineal foot of span [illegible] the corresponding known weight T for a span of length [illegible] per lineal foot remaining unchanged, the following appro[illegible] will serve for spans of ordinary length—say up to five hu[illegible]

$$T' = T\frac{l'}{l};$$

while for longer spans there may be used the formula,

$$T' = \frac{T}{2}\left[\frac{l'}{l} + \left(\frac{l'}{l}\right)^2\right].$$

To find for any span length the truss weight T' [illegible]

[illegible]

[illegible] ordinary spans, but for very long [illegible] between T' and T. After finding the [illegible] should be checked, and if there be any [illegible] the assumed and that found, the [illegible] anew, and so on until a satisfactory [illegible] of p' be obtained.

[illegible] correct formulæ for weights per lineal [illegible] from the diagrams given in this chapter [illegible] to any one who cares to copy them. [illegible] l is the span length in feet, W is the weight [illegible] lineal foot of span, and P is the total load [illegible] by the truss. They should not be used [illegible] the limits noted.

TABLE 55a

[illegible] FOR TRUSS WEIGHTS

[illegible]	Range of P ([illegible])	Formula
[illegible]	3,000–18,000	$W = 180 + \frac{(l - 50)\,P}{1480}$
[illegible]	3,000–18,000	$W = 180 + \frac{(l - 70)\,(P + 300)}{1370}$
[illegible]	3,000–13,000	$W = 180 + \frac{(l - 30)\,P}{1590}$
[illegible]	3,000–13,000	$W = 180 + \frac{(l - 80)\,P}{1130}$
[illegible]	3,000–18,000	$W = \frac{(l - 25)\,(P + 1700)}{1800}$

[illegible] 55a can be employed instead of Equations 5 [illegible] will give more accurate results. If the weight [illegible] some given specification is known, it can be [illegible] proper formulæ, and a new value of the denomi[illegible] l and P can then be computed. This pro[illegible] which will apply quite closely for the given [illegible]

[illegible] formulæ of Table 55a, similar results can be [illegible] of a known truss or girder weight under a [illegible] for a similar truss or girder of the same

span-length and loading as diagrammed in Figs.

assuming this ratio to be the same for any other span

If a railway bridge is to be designed for substantially the same stresses as those of Chapter LXXVIII, but for a different loading impact than those adopted for this treatise, the following method be employed, as it is simple and very accurate. First find the sum equivalent uniform live load and the impact load, assuming a length equal to one and one-half panels, for the specified loading also for Class 50 of this treatise; and call the ratio of the first sum to second one *r*. The said loading is then equivalent to Class 50 × *r*, far as the floor system is concerned; and the floor system weight for equivalent class is then read (by interpolation if necessary) from proper curve. The equivalent class of loading for the full span-leng is then found in a similar manner, and the weights of the laterals, on piers, and the trusses are determined from the proper curves. Un either the arrangement of the locomotive axles or the impact curve much unlike that of this treatise, it will be sufficiently accurate to com pute merely the equivalent class of loading for the full span-length, then employ the proper curve for the total weight of metal in the If a Cooper standard loading be adopted, and the impact formula of treatise be employed, the curves will give the weights directly small margin on the safe side. If a Cooper loading be used with other impact formula, the equivalent class of loading will be equal said Cooper loading multiplied by the ratio

$$\frac{1 + I'}{1 + I}$$

where I' is the impact adopted, and I is that given by the formula this treatise. The same method will, of course, apply if the standard loadings of this treatise be used with some other impact formula.

From the author's paper on "The Possibilities in Bridge Constructi by the Use of High Alloy Steels" are made the following extracts relati to the finding of metal weights in alloy steel bridges from those in simil carbon steel bridges and to the theory of weight curve extensions beyo the limits of actually designed structures.

"The following are the formulæ of reduction used in passing from known of metal per lineal foot of span in carbon-steel bridges to the corresponding alloy-steel bridges. An observation of the nomenclature will show that the capital letters severally represent weights of metal per lineal foot of span steel bridges (or otherwise known weights of bridges of any kind of steel accented capital letters, the corresponding weights for alloy-steel bridges the corresponding unknown weights of bridges of some other kind the small letters severally represent lineal dimensions of structures, the being that capital *R* is used for reactions and small *r* for ratios.

"*Floor System.*—

Let F = weight of metal per lineal foot of span in the 'Floor
steel bridges;

[illegible]

including anchorage material in the case of cantilever

weight of the floor system will vary inversely with the remainder will be invariable.

$$F = V + I. \qquad \text{[Eq. 9]}$$

metal per lineal foot of span in the floor system of alloy-

) = the ratio of elastic limits of alloy steel and carbon

$$F' = I + \frac{V}{r}. \qquad \text{[Eq. 10]}$$

bridges, and especially those of long span, I will be approximately 0.65 F, hence

$$0.35\, F + \frac{0.65\, F}{r} = F\left(0.35 + \frac{0.65}{r}\right). \qquad \text{[Eq. 11]}$$

greater length than any of those yet actually computed, the increasing width of structure will augment the weight consequently, the weight of metal per lineal foot of span for of double-track cantilever bridges, an economy can be cantilever arms and the anchor arms uniformly from ends it probable that motives of policy would lead the projectors spans so as to carry more than two tracks.

at which it pays to begin to use high steel for the laterals ends of l_1, it being assumed that the weight of laterals is the entire length l_1, or, in other words, that minimum therein throughout;
end of l_1;
end of span l;
unity) of R and R_1;
steel per lineal foot for lateral system over the length l_1;
carbon and alloy steels per lineal foot of span at end of

$$L'_a = L_1\left(0.3 + 0.7\frac{r_w}{r}\right). \qquad \text{[Eq. 12]}$$

metal per lineal foot for entire span l.

$$\left\{ L_1\, l_1 + \frac{L'_a + L_1}{2}(l - l_1) \right\}. \qquad \text{[Eq. 13]}$$

L_1, it shows that near the ends of the span minimum used and that L'_a will equal L_1.

of actually figured spans, when computing the weights be remembered that, as just explained for the floor increased, not only because of the greater span length width. As a rule, it may be stated that, for any remaining constant), the effect of increasing the

width between central planes of trusses n per cent is to increase the weight of metal in the lateral system about $\frac{n}{2}$ per cent.

"*Trusses.*—In respect to the weight, T, of metal per lineal foot of span for trusses of carbon steel, the following equation may be used:

$$T = K + T_1 + C_c + C_w, \qquad \text{[Eq. 14]}$$

where K is the portion of the total truss weight per lineal foot which is independent of the quality of the metal and of the stresses; T_1 is that of the main portions of the tension members and of their details that are directly affected by the stresses; C_c is that of the main portions of the compression chords and inclined end posts and their details that are directly affected by the stresses; and C_w is that of the main portions of the compression web members.

"From experience in designing large bridges it may be stated that, as an average,

$$K = 0.2T,$$
$$T_1 = 0.3T,$$
$$C_c = 0.3T,$$
and
$$C_w = 0.2T.$$

"Both T_1 and C_c (and consequently their sum) will vary inversely with the elastic limit of the metal; but C_w, on account of the influence of the ratio of strut length to least radius of gyration, will not vary in that ratio. As an approximation it may be assumed that, in passing from any grade of steel to a higher grade, if, as before, r (greater than unity) is the ratio of the elastic limits of the two metals,

$$C'_w = \frac{1}{2} C_w \left(1 + \frac{1}{r}\right), \qquad \text{[Eq. 15]}$$

and

$$C'_c = \frac{C_c}{r}. \qquad \text{[Eq. 16]}$$

"Substituting these values in Equation 14, we have

$$T' = K + \frac{1}{r}\left(T_1 + C_c\right) + \frac{1}{2} C_w \left(1 + \frac{1}{r}\right). \qquad \text{[Eq. 17]}$$

"Substituting the values of K, T_1, C_c, and C_w in terms of T as previously given, we have

$$T' = T\left(0.3 + \frac{0.7}{r}\right). \qquad \text{[Eq. 18]}$$

"In finding the new truss weight per lineal foot for a higher steel, after computing it (as just indicated) for the direct effect of increased elastic limit, it must be corrected for the indirect effect, which is the changed total load per lineal foot for trusses. This correction is made thus:

"Find the sum of the live load, impact load, and dead load per lineal foot of span, for the known truss weight, T, and then determine approximately the corresponding sum (on the basis of an assumed final value of T'_f) for the new truss weight. Let the ratio of these sums (less than unity) be r_1.

Then

$$T'_f = T'\,(0.3 + 0.7\,r_1), \qquad \text{[Eq. 19]}$$

where T'_f is the final value of the truss weight. Combining Equations 18 and 19 gives

$$T'_f = T\left(0.3 + \frac{0.7}{r}\right)(0.3 + 0.7\,r_1). \qquad \text{[Eq. 20]}$$

"If the computed value of T'_f does not agree quite closely with its value adopted in determining the trial dead load, a new dead load is to be assumed, and the calculations are to be made afresh. The second attempt, in all probability, will give a sufficiently accurate agreement.

"*On Piers.*—To find the new value, P′, from the old value of P, the span length being unchanged, the following approximately correct equation may be used:

$$P' = P\left(0.6 + \frac{0.4}{r}\right) r_1, \qquad \text{[Eq. 21]}$$

where r and r_1, respectively, are the ratios previously indicated for elastic limits and total loads per lineal foot of span.

"In extending a curve of simple truss weights of metal per lineal foot of span beyond the limits of accurate computations, the following formulæ may either be used directly or as a check, the character of the steel, of course, being unchanged. Assume first that the live and the dead loads per lineal foot of span remain constant, and consider the effect only of longer spans and greater truss depths. Dealing first with the chords, some 85 per cent of their weights of metal per lineal foot of span vary directly as the moments of the total loads and inversely as the truss depths; but the moments vary as the squares of the span lengths, and the stresses are inversely as the truss depths. Again, the truss depths within short limits may, without serious error, be taken to vary directly as the span lengths. Such being the case, 85 per cent of the weights per foot of the chords will vary directly as the span lengths, or

$$C' = 0.15\,C + 0.85\,C\frac{l'}{l} = C\left(0.15 + 0.85\frac{l'}{l}\right), \qquad \text{[Eq. 22]}$$

where C is the chord weight per foot for the shorter span, l, and C' is the corresponding weight for the longer span, l'.

"Let W and W' be, respectively, the weights of metal per lineal foot of span in the webs of the two spans. About 75 per cent of these will vary directly as the averages of all the live-load and dead-load shears on the spans, and these average shears vary almost directly as the span lengths. Again, the said 75 per cent of W and W' will vary directly as the truss depths, and, therefore, as previously assumed, once more directly as the span lengths.

"Combining these ratios will give the equation:

$$W' = 0.25\,W + 0.75\,W\left(\frac{l'}{l}\right)^2 = W\left\{0.25 + 0.75\left(\frac{l'}{l}\right)^2\right\}. \qquad \text{[Eq. 23]}$$

But

$$T = C + W,$$

and

$$T' = C' + W' = C\left(0.15 + 0.85\frac{l'}{l}\right) + W\left\{0.25 + 0.75\left(\frac{l'}{l}\right)^2\right\}. \qquad \text{[Eq. 24]}$$

"It is well known that in trusses with parallel chords and of economic depths the weight of the chords is equal to the weight of the web; but, in trusses with polygonal chords and having centre depths less than the theoretically economic ones, as do those of all long-span bridges, the weight of the chords is much greater than that of the web. As a general average, we may assume that $C = 0.6\,T$, and $W = 0.4\,T$.

Hence

$$T' = 0.6\,T\left(0.15 + 0.85\,l'\right) + 0.4\,T\left\{0.25 + 0.75\left(\frac{l'}{l}\right)^2\right\}$$

$$= T\left\{0.19 + 0.51\frac{l'}{l} + 0.3\left(\frac{l'}{l}\right)^2\right\}. \qquad \text{[Eq. 25]}$$

"This value of T' is based on the incorrect assumption that the total loads per

lineal foot of span are the same for both spans under a further modification, as follows:

$$T'_f = T'' (0.2 + 0.8\, r_1),$$

where T'_f is the final value of the weight of truss metal per lineal span, and r_1 (in this case greater than unity) is the ratio of the total loads per

"Combining Equations 25 and 26, we have

$$T'_f = T \left\{0.19 + 0.51 \frac{l'}{l} + 0.3 \left(\frac{l'}{l}\right)^2 \right\} (0.2 + 0.8\, r_1).$$

"A test of this formula, on carefully computed curves of truss weights for spans of nickel steel from 600 to 1,000 ft. in length, shows that slightly undue nence has been given to the invariable portion of the weights, and that the modification of the formula will give more accurate results:

$$T'_f = T \left\{0.15 + 0.55 \frac{l'}{l} + 0.3 \left(\frac{l'}{l}\right)^2 \right\} (0.15 + 0.85\, r_1).$$

"This last formula, when tested on the truss weights of simple spans from to 1,000 ft. in length for an elastic limit of 90,000 lbs., gave exceedingly close hence it is proper to adopt it as the equation for extension of all truss weights ple spans, and, inferentially, for those of cantilever bridges; in fact, it has been on some of the actually computed truss weights of cantilever bridges and give excellent agreement.

"Attention is called to the semi-rational, semi-empirical character of these tion and extension formulæ. They are, in general, the result of long personal ence in the quick computation of metal weights for bridges; but they have fied slightly, as hereinbefore indicated, to agree with certain checks that made in this investigation. As far as practicable, the formulæ of Equations were used for checking each other; and the results of such checks were factory. For instance, if a curve of truss weights for one class of steel a basis for finding, by Equation 20, the corresponding curve for another the latter curve would be checked by starting from any desired point the weights of actually computed bridges cease) and passing, by using from one span length to another, 100 or 200 ft. greater, and continuing to the superior end of the curve."

The reader who is interested not only in the weights of bridges but also in the economics of structures built of various steel, is advised to read the paper on "The Possibilities in struction by the Use of High Alloy Steels," from which several preceding pages have been copied. It was published in the of the American Society of Civil Engineers, Vol. LXXVIII,

ILLUSTRATIVE EXAMPLES

In order to demonstrate how to use the various diagrams of metal given in this chapter, certain characteristic examples solutions will now be presented. The numerical values carried out only to that degree of accuracy which good rants, and as indicated in Table 58*a*.

A. What weight of metal per lineal foot would be

span to carry a Class 55 live

find the intersection of a vertical line through
the inclined line for Class 55, and pass from
right vertical where the reading gives 1420.
that the effective length from centre to centre
feet instead of 90 feet.

weight of steel per lineal foot in a single-track,
truss span of 182 feet to carry a Class 65 live
distributed between the different portions of the

55e, 55g, and 55h, we find the following:
for the weight of the Lateral System 220 pounds,
pounds.
are seven panels of 26 feet each, then Fig. 55e
Floor System 650 + 10 = 660 pounds.
parallel chords a truss weight of 1,680 pounds.
weights is 2,690 pounds.
gives for the total weight of metal per lineal
exact coincidence is impracticable to obtain ex-
to the slight errors involved in reading the quan-
various intersecting lines on the several diagrams,
slight difference in the weight of the floor system
length.

weight of metal in a single-track, deck, riveted
long, in nine equal panels, and having a width
planes of trusses, the live load being Class 40;
divided?

the total weight of metal per lineal foot of span

pounds of this are contained in the trusses.
for the floor system is found thus: At the
horizontal line for a 30-foot panel is followed
curve; the vertical through the intersection is
line, and the horizontal through this inter-
vertical, indicates that the weight is 530 pounds.
of the metal on piers as 80 pounds, and
pounds; and it also shows that the best
the proper perpendicular distance between
feet, as was assumed.
weights is 3,020 pounds, checking that first
which is close enough.
metal weights for a double-track-railway,
bridge of 720 feet span designed for

[illegible] the weight of metal in the trusses 16,100 pounds.

[illegible] indicates 1,770 pounds for the floor-system, 800 pou for the lateral system, and 320 pounds for the metal on piers.

The sum of the last four weights is 18,990 pounds, which varies fr the value first found by only one-twentieth of one per cent.

E. What are the various weights of metal in a single-track, pi connected, centre-bearing swing-span 440 feet long, to carry a Class live load?

The weight of the floor system is the same as that for a similar fix span in which the perpendicular distance between central planes of trus is the same. In this case the distance will be the minimum allowab or about 17.5 feet. Assume the panel length for each arm to be 26 feet and that at the tower 17.5 feet. Fig. 55n gives the weight as 64 pounds.

For the laterals we must use Fig. 55d and a span length of 0.7 × 440 = 308 feet, which gives the weight as 310 pounds.

For the truss weight we must use Fig. 55o and a span length of 0.6 × 440 = 264 feet. This indicates a weight of 2,130 pounds.

The sum of these three weights is 3,080 pounds, and to this must be added about 30 per cent for the drum, machinery, and metal on piers, making 4,010 pounds for the total weight of metal.

As a rough check on this, Fig. 55ee gives 78.5 per cent as the figure to apply to the total weight of metal for a 440-foot fixed span, which weight Fig. 55q shows to be 5,270 pounds. 78.5 × 5,270 = 4,140 pounds, indicating a difference of 130 pounds or about three per cent. This check, at first thought, may not be deemed sufficiently accurate, but it must be remembered that, as a matter of precaution, in order to provide for the individual idiosyncrasies of bridge designers and to be on the safe side, the percentages in Fig. 55ee have been kept somewhat high. Again, it must not be forgotten that the methods herein suggested for finding the weights of swing spans are not claimed to be as accurate as those given for finding the weights of fixed spans.

F. What are the economic functions and weights of metal for a single-track railway trestle 200 feet high with a batter of an inch and a half to the foot, to carry a Class 55 live load? It is assumed that there are no restrictions as to the lengths of bays and that alternate spans are tower spans.

From Fig. 55oo it is seen that the best length for the intermedia spans is 82 feet, and that the length for the tower span is given as 45 fe Actually the lengths chosen would probably be 80 and 40 feet, and th variation in weight caused by such a departure from exact econom would be very small. For the economic layout we have the follow weights, taken from Figs. 55nn to 55qq, inclusive.

[illegible] lbs.

= 115,110 lbs. Average weight = [illegible] lbs.

Girder Bracing

See Fig. 55nn

= 8,610 lbs.

= 2,030 lbs.

= 10,640 lbs. Average weight = 84 lbs.

Longitudinal Bracing

See Fig. 55pp

400 × 200 + 127 = 630 lbs.

Transverse Bracing

See Fig. 55pp

410 × 200 + 127 = 640 lbs.

Columns

See Fig. 55qq

810 × 200 + 127 = 1,275 lbs.

Total = 3,536 lbs.

Fig. 55rr gives a total weight per lineal foot of

example it had been necessary to make the tower the intermediate spans 60 feet long, what would weights of metal?

grams we have the following:

Girders

See Fig. 55nn

= 46,200 lbs.

= 21,200 lbs.

= 67,400 lbs. Average weight = 674 lbs.

Girder Bracing

See Fig. 55nn

= 3,600 lbs.

= 1,600 lbs.

5,200 lbs. Average weight = 52 lbs.

Longitudinal Bracing

See Fig. 55*pp*

410 × 200 ÷ 100.......... 820 lbs.

Transverse Bracing

See Fig. 55*pp*

410 × 200 ÷ 100.......... 820 lbs.

Columns

See Fig. 55*qq*

658 × 200 ÷ 100..........1,320 lbs.

Total................3,686 lbs.

This indicates an excess of metal equal to 150 pounds per lineal foot, or over four per cent, due to the uneconomic layout.

H. A single-track-railway trestle 60′ high is laid out with towers 30′ long and two intermediate solitary bents between adjacent towers, the batter of columns being one and a half inches to the foot. It is to carry a Class 70 loading. What are the economics and the weights of metal?

From Fig. 55*zz* the best length of the intermediate span is seen to be about 40 feet.

The weights are determined as follows:

Girders

See Fig. 55*tt*

Average weight per foot.................... 575 lbs.

Girder Bracing

See Fig. 55*tt*

Average weight per foot.................... 40 lbs.

Towers and Bents

See Fig. 55*yy*

Average weight per foot for 40-foot intermediate spans......................... 925 lbs.

Total.............................. 1,540 lbs.

Fig. 55*zz* makes this total 1,540 lbs., which checks exactly.

I. If in Case F the trestle had carried a double track, what would have been the various weights of metal?

Applying the rules given, we find the following:

[illegible] . . . . . . [illegible] lbs.
[illegible] × 1.9 . . . . 1,184 lbs.
[illegible] 640 × 1.7 . . . . 1,088 lbs.
[illegible] × 1.6 . . . . 2,040 lbs.
[illegible] . . . . 6,234 lbs.

[illegible] economic functions and the weights of metal for a [illegible] railway trestle, Type I, 150 feet high with columns [illegible] the foot transversely, to carry Class 30 live load, [illegible] a four-degree curve, and the minimum allowable [illegible] being $\frac{5}{16}''$?

[illegible] the economic lengths of spans, it will be necessary [illegible] railway live load to which Class 30 corresponds. [illegible] steam railway live loads as a basis, and assuming [illegible] length, we have the following:

[illegible] Class 30 Electric Railway
[illegible] (Fig. 6h) . . . . 2,230 lbs. per lin. ft.
[illegible] 7d) – 47 per cent . . . 1,050 lbs. per lin. ft.
[illegible] + L.L. . . . . 3,280 lbs. per lin. ft.

[illegible] Class 40 Steam Railway
[illegible] 6d) . . . . 5,460 lbs. per lin. ft.
[illegible] 7e) – 71.7 per cent . . 3,920 lbs. per lin. ft.
[illegible] + L.L. . . . . 9,380 lbs. per lin. ft.

[illegible] = 0.35.

[illegible] railway therefore corresponds to Class 40 × 0.35 = [illegible]

[illegible] Fig. 55oo, we find the proper length of tower span to [illegible] that of the intermediate span, for a Class 14 load- [illegible] feet. We shall adopt 40 feet for the tower span [illegible] intermediate span. The erection of a span longer [illegible] a rather difficult proceeding, or at least uneco- [illegible] distance from centre to centre of towers 130 feet. [illegible] find the weights of the various portions in the [illegible]

[illegible] *and Girder Bracing*

90′ Span

[illegible] span (Fig. 6h) . . . . . . 2,200 lbs. per lin. ft.
[illegible] 7d) . . . . 990 lbs. per lin. ft.
[illegible] . . . . 400 lbs. per lin. ft.
[illegible] (Fig. 55nn) 680 + 110 = 790 lbs. per lin. ft.
[illegible] . . . . 4,380 lbs. per lin. ft.
[illegible]

[illegible] (Fig. [illegible] [illegible] assumed in finding the [illegible] [illegible] this result is satisfactory.

Weight of girder bracing (Fig. 55nn) = 110 × 0.8 .... 88 [illegible]

Total weight of girder and bracing .... 648 lbs. per [illegible]

40′ Span

Live load, Class 30, 40′ span (Fig. 6h) ...... 2,900 lbs. per lin. ft.

Impact, 56 per cent (Fig. 7d) .... 1,620 lbs. per lin. ft.

Dead load,

Deck .... 400 lbs. per lin. ft.

Girders and bracing (Fig. 55nn) = 330 + 40 .... 370 lbs. per lin. ft.

Total .... 5,290 lbs. per lin. ft.

or 2,700 lbs. per lin. ft. per girder.

Weight of girders (Fig. 55ff) = 2 × 145 ..... 290 lbs. per lin. ft.

As the weight assumed in finding the load on the girder was 330 pounds this result is satisfactory.

Weight of girder bracing (Fig. 55nn) = 40 × 0.8 .... 32 lbs. per lin. ft.

Total weight of girders and bracing .... 322 lbs. per lin. ft.

Average weight per lineal foot of

$$\text{structure} = \frac{(90 \times 648) + (40 \times 322)}{130} = 548 \text{ lbs. per lin. ft.}$$

Transverse Bracing of Towers

See Fig. 55pp

$$415 \times \frac{150}{130} \times 0.8 \ldots\ldots\ 383 \text{ lbs. per lin. ft.}$$

Longitudinal Bracing of Towers

See Fig. 55pp

$$410 \times \frac{150}{130} \times 0.8 \ldots\ldots\ 378 \text{ lbs. per lin. ft.}$$

Columns of Towers

See Fig. 55rr

Class 40 railway loading gives 610 lbs. per vert. ft. (Fig. [illegible]

Class 30, $C_E = 610(0.2 + 0.8 \times 0.35) = 293$ lbs. per vert. ft. [illegible]

$$293 \times \frac{150}{130} \ldots\ldots\ 338 \text{ lbs.}$$

Total metal in structure on tangent ..... 1,647 lbs. [illegible]

Add for effect of 4 degree curve 1,647 × .08 .. 132 [illegible]

Total metal in structure .... 1,779 [illegible]

railway of Class 60 … of the …
… railway (Class 35) and …
… with creosoted blocks, resting upon …
… on each side outside of the trusses, …
… C live loading) of four-inch granitoid outside of …
… is the weight of metal per lineal foot for the …

… lineal foot for one truss are as follows:

[illegible]	6,800 lbs.	(From Fig. 8e)
[illegible] 17 per cent	1,156 lbs.	(From Fig. 7c)
[illegible]	1,310 lbs.	(From Fig. 8b)
[illegible] 12½ per cent.	227 lbs.	(From Fig. 7d)
[illegible] × 49	294 lbs.	(From Fig. 6e)
[illegible] 10 per cent.	29 lbs.	(From Fig. 7e)
[illegible]	10,316 lbs.	

… load per lineal foot per truss will be as follows:

[illegible]	500 lbs.
[illegible] 12 × 90	1,080 lbs.
[illegible]	300 lbs.
[illegible]	60 lbs.
[illegible]	40 lbs.
[illegible] (Fig. 55a)	700 lbs.
[illegible] say	600 lbs.
[illegible]	300 lbs.
[illegible]	6,000 lbs.
[illegible]	9,580 lbs.
[illegible] impact loads	10,316 lbs.
[illegible]	19,896 lbs.

… 20,000 lbs.

… we find for a total load of 20,000 lbs. and a … of about 4,900 lbs., which shows that the truss … high. Assuming a new truss weight of 4,600 … total load 18,496 lbs., for which the diagram … lbs. This checks closely, hence the weight for … 2 × 4,550 = 9,100 lbs.

… cantilevers are employed in exactly the same man- … spans, there is no need for providing an ex- … utilization.

CHAPTER LVI

QUANTITIES FOR PIERS, PEDESTALS, ABUTMENTS, RETAINING WALLS, AND REINFORCED CONCRETE BRIDGES

MANY of the tables and diagrams given in this chapter have been prepared from time to time during the last three decades of the author's practice in order to facilitate the calculation of quantities of materials in substructure and masonry work. They have been found so convenient that it has been deemed worth while to reproduce them here for the benefit of bridge engineers in general, and to add to them materially so as to cover, to as great an extent as practicable, all lines of bridgework, including reinforced concrete construction.

PIERS

In Fig. 56*a* are given the volumes of copings and of shafts of piers with vertical sides. The curves thereof are of little value for the shafts of ordinary piers, as these are generally battered. For solid circular pivot-piers, as well as for any coping, the curves can be used advantageously. To apply the diagram for the vertical shaft of any pier or any coping, it is necessary to enter at the lower margin with the width of the shaft or coping in feet, trace vertically to the curve for the length of the tangent portion, and pass horizontally to the right or left margin, where will be indicated the volume for one foot of height. This quantity multiplied by the height will give the total volume in the pier-shaft or coping. It will be noted that the lower curve, for which the length of the tangent portion of the shaft is zero, applies directly to circular piers.

Figs. 56*b*, 56*c*, 56*e*, 56*f*, 56*h*, and 56*i* give the volumes in cubic yards of the truncated cones formed by bringing together the rounded ends of battered piers. They are for batters of one-half, three-quarters, and one inch to the foot, which are those generally used in pier designing. Figs. 56*d*, 56*g*, and 56*j* give the volumes in cubic yards for one-foot-wide strips of pier between the rounded ends for batters of one-half, three-quarters, and one inch to the foot.

To find the total volume of any pier, add together that of the coping, that of the two rounded ends which form a truncated cone, and the product of the volume of a one-foot strip by the length of the portion of the pier between the vertical axes of the rounded ends.

PEDESTALS

In Figs. 56*k*, 56*l*, and 56*m* are given the volumes of the shafts of concrete pedestals, up to heights of twenty feet, for tops from 2.5 to 5.5 feet square. Each of these diagrams covers all standard batters from one inch to six inches per foot, varying by half inches. As it is not customary today to put copings on concrete pedestals, the total volume for the shaft of any pedestal can be taken directly from one of these diagrams. Should any intermediate batter be employed, which is unlikely, the approximately

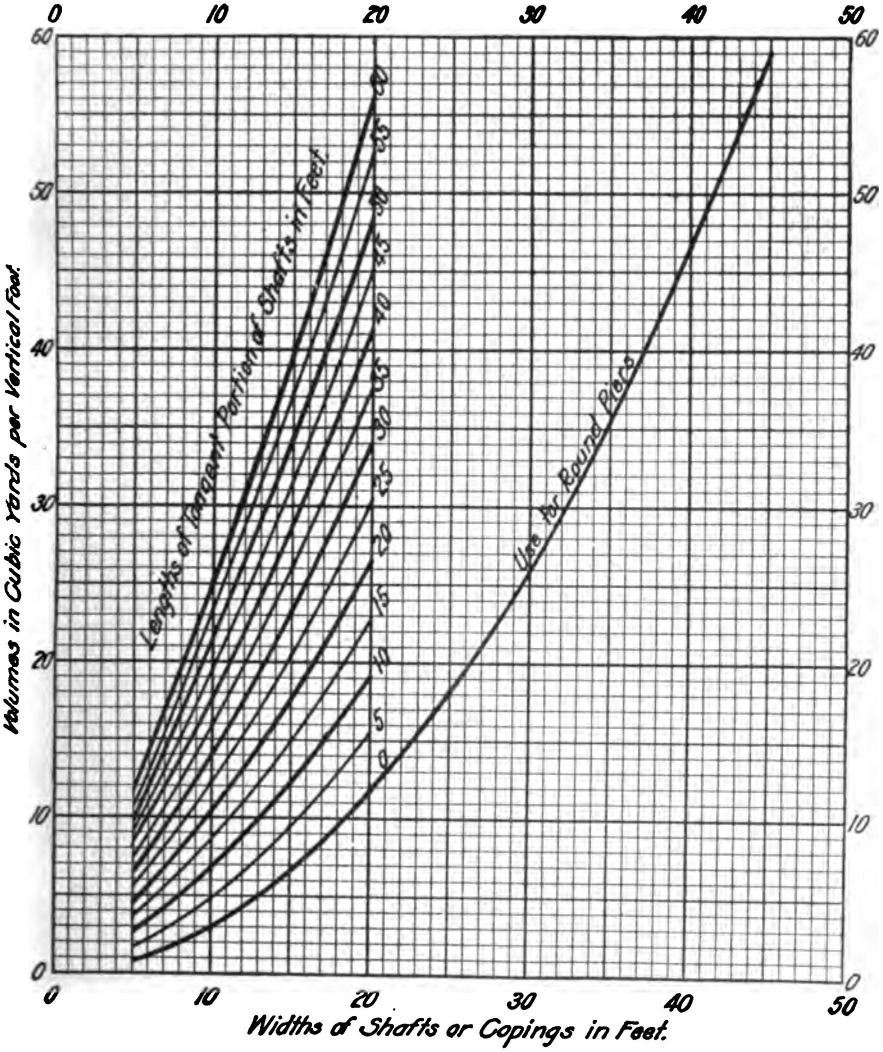


FIG. 56*a*. Volumes of Copings and of Shafts of Piers with Vertical Sides.

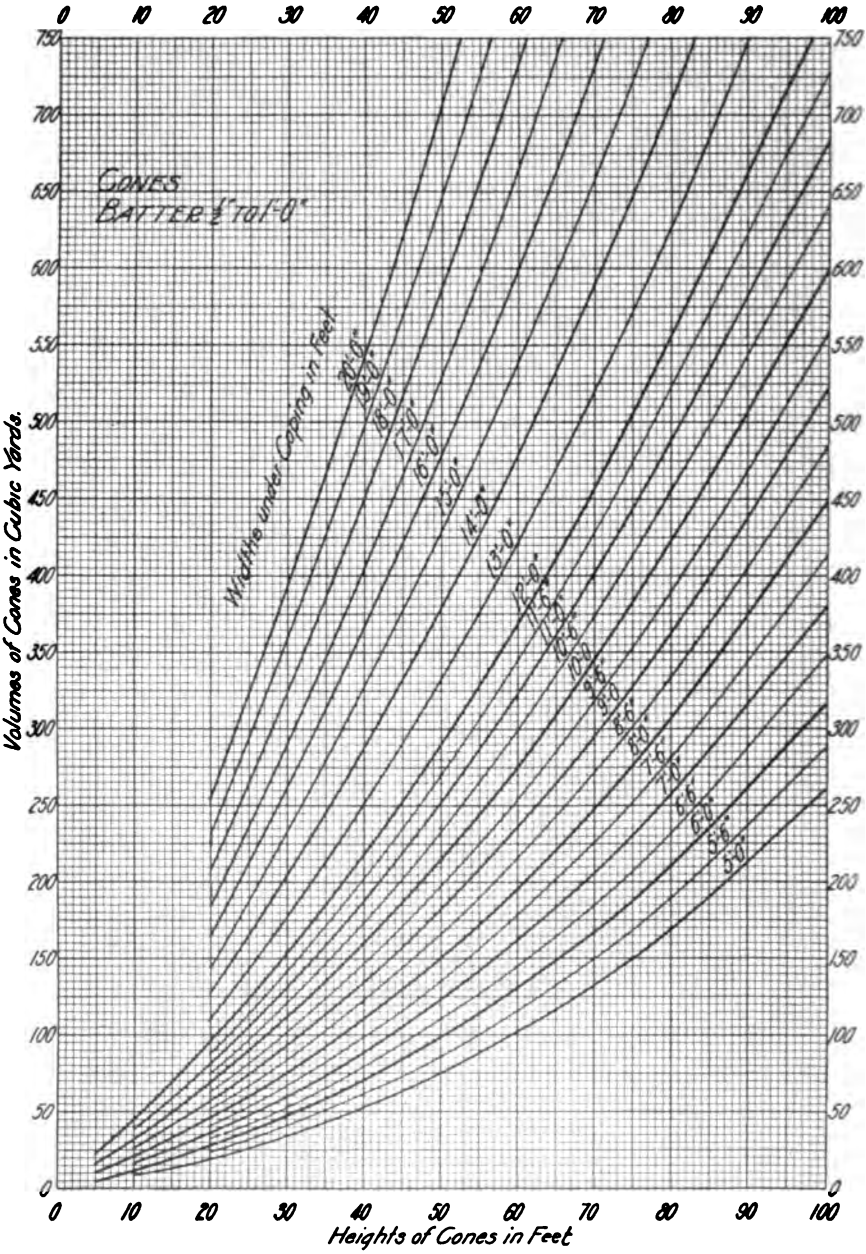
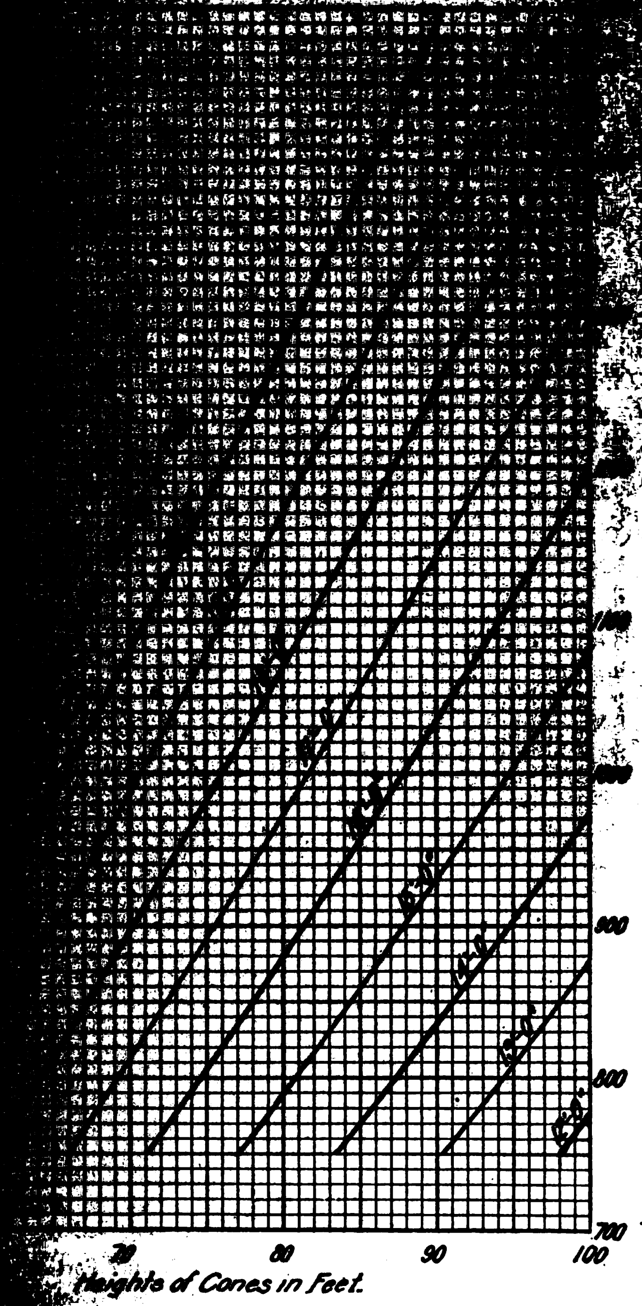


FIG. 56*b*. Volumes of Truncated Cones Composed of Two Rounded Ends of Piers—Batter ½" to 1' 0".



ted Cones Composed of Two Rounded Ends of Piers—
Batter ½" to 1' 0".

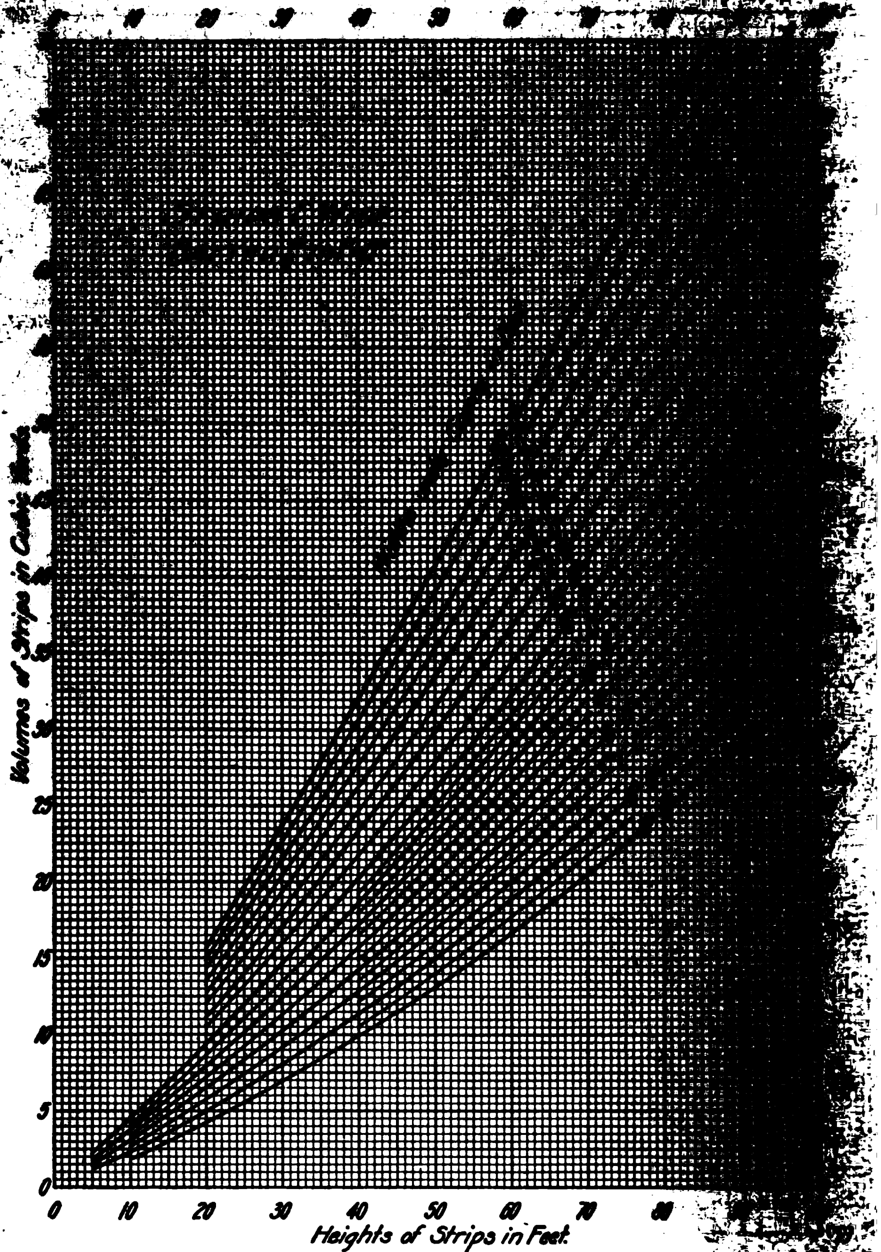
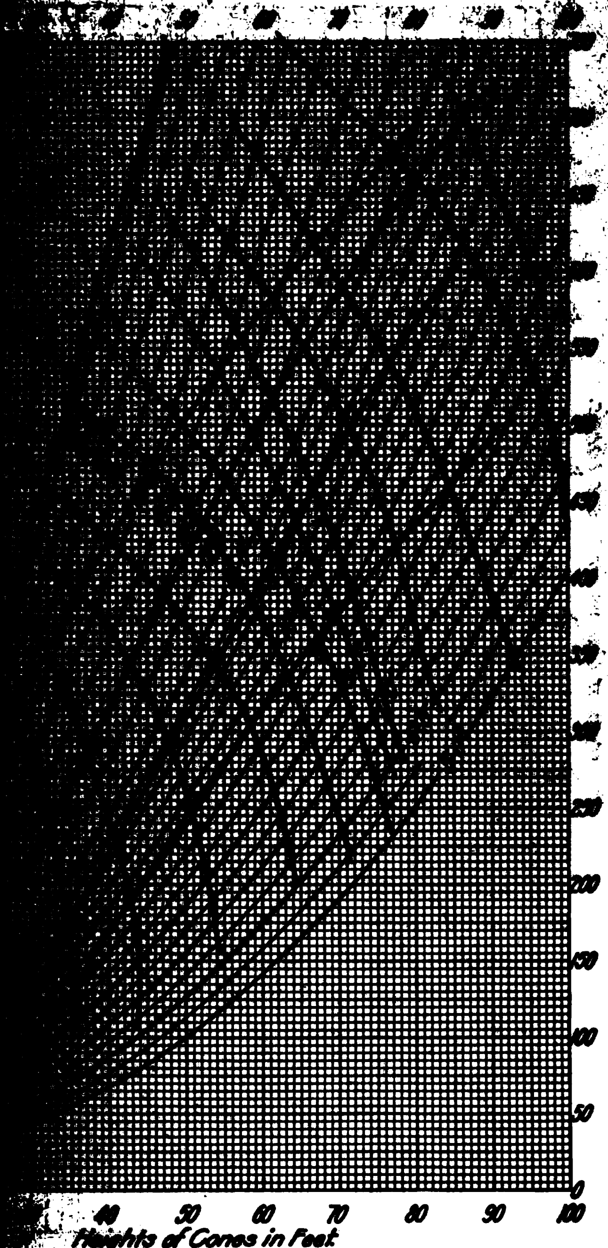


FIG. 56d. Volumes of Strips One Foot Wide in Middle Portion of Round-[illegible] Batter ½″ to 1′ 0″.



ated Cones Composed of Two Rounded Ends of Piers—Batter ¾" to 1' 0".

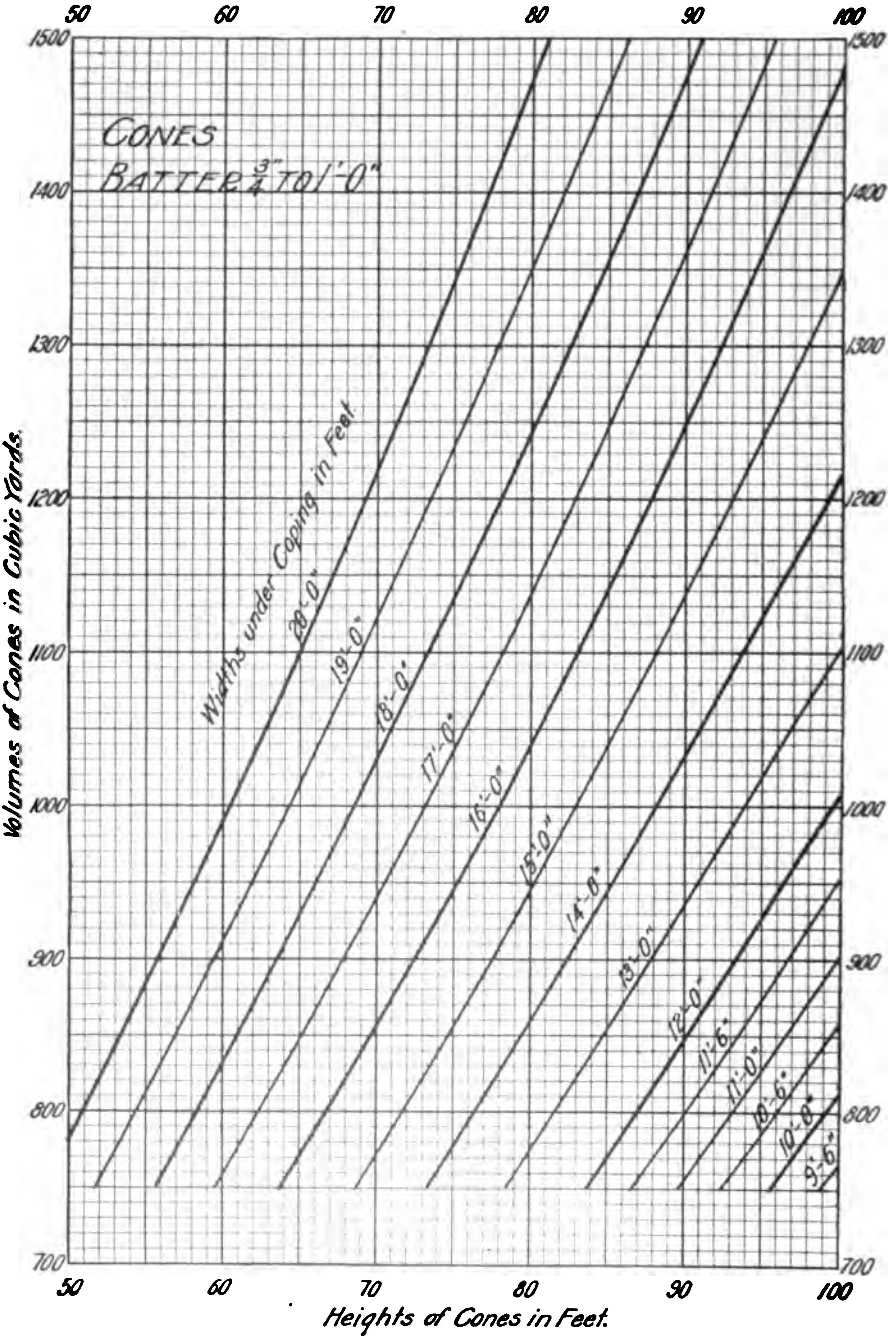


FIG. 56*f*. Volumes of Truncated Cones Composed of Two Rounded Ends of Piers—Batter 3/4" to 1' 0".

Foot Wide in Middle Portion of Round-Ended Piers—
Batter ⅛″ to 1′ 0″

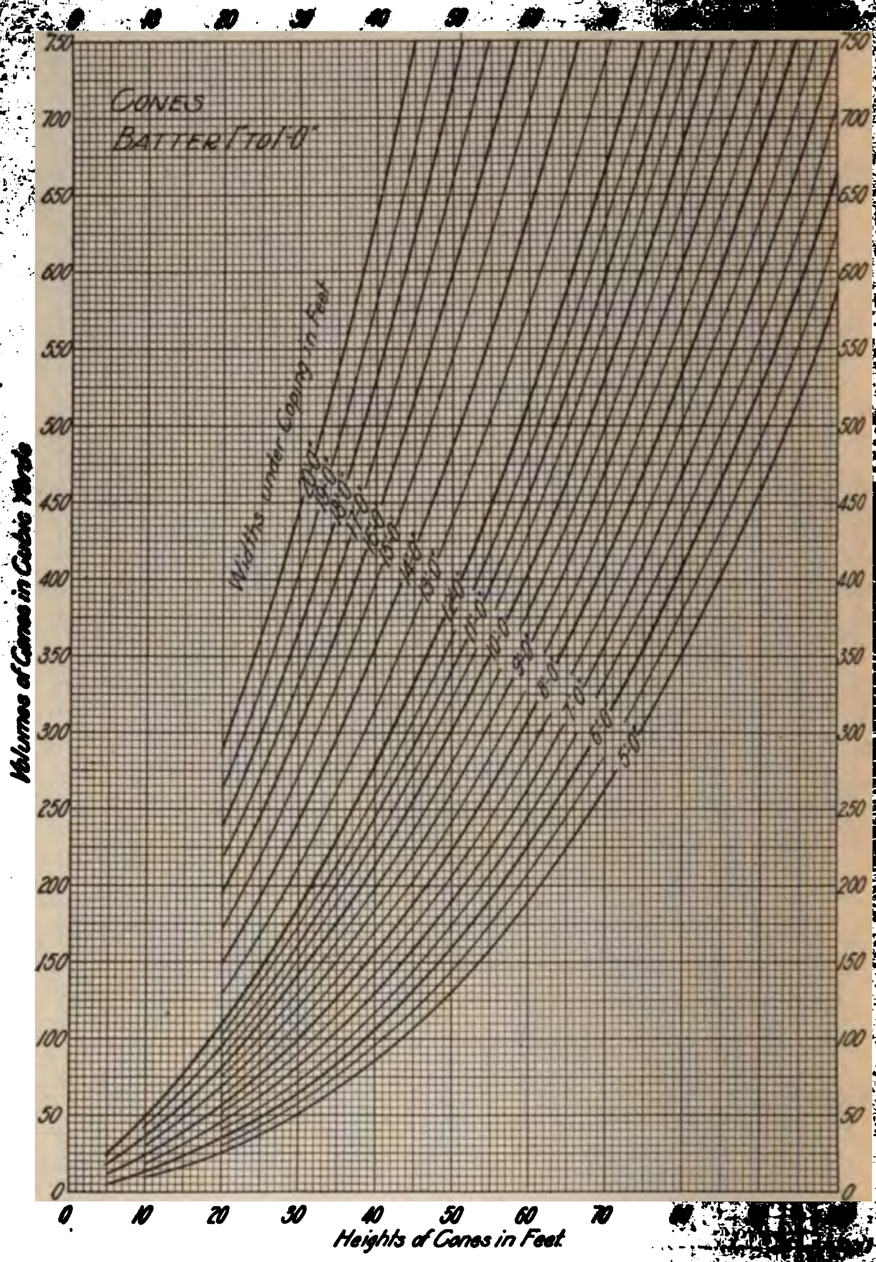
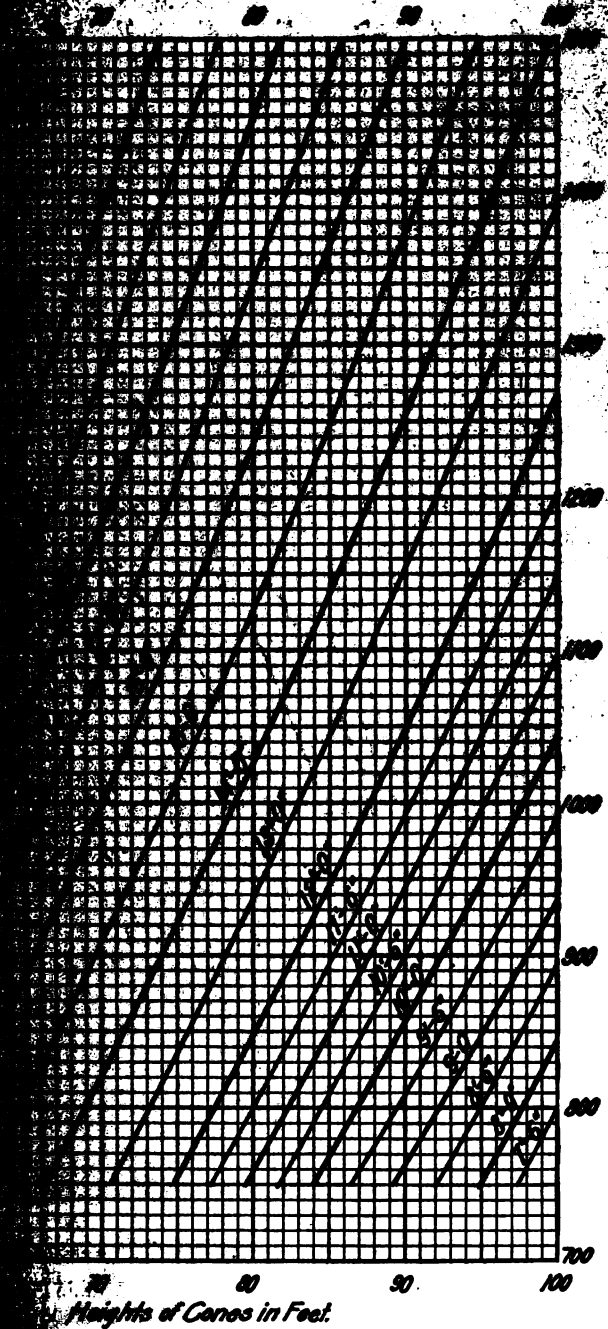


Fig. 56h. Volumes of Truncated Cones Composed of Two Rounded [illegible] Batter 1" to 1' 0".



Cones Composed of Two Rounded Ends of Piers—
Batter 1″ to 1′ 0″.

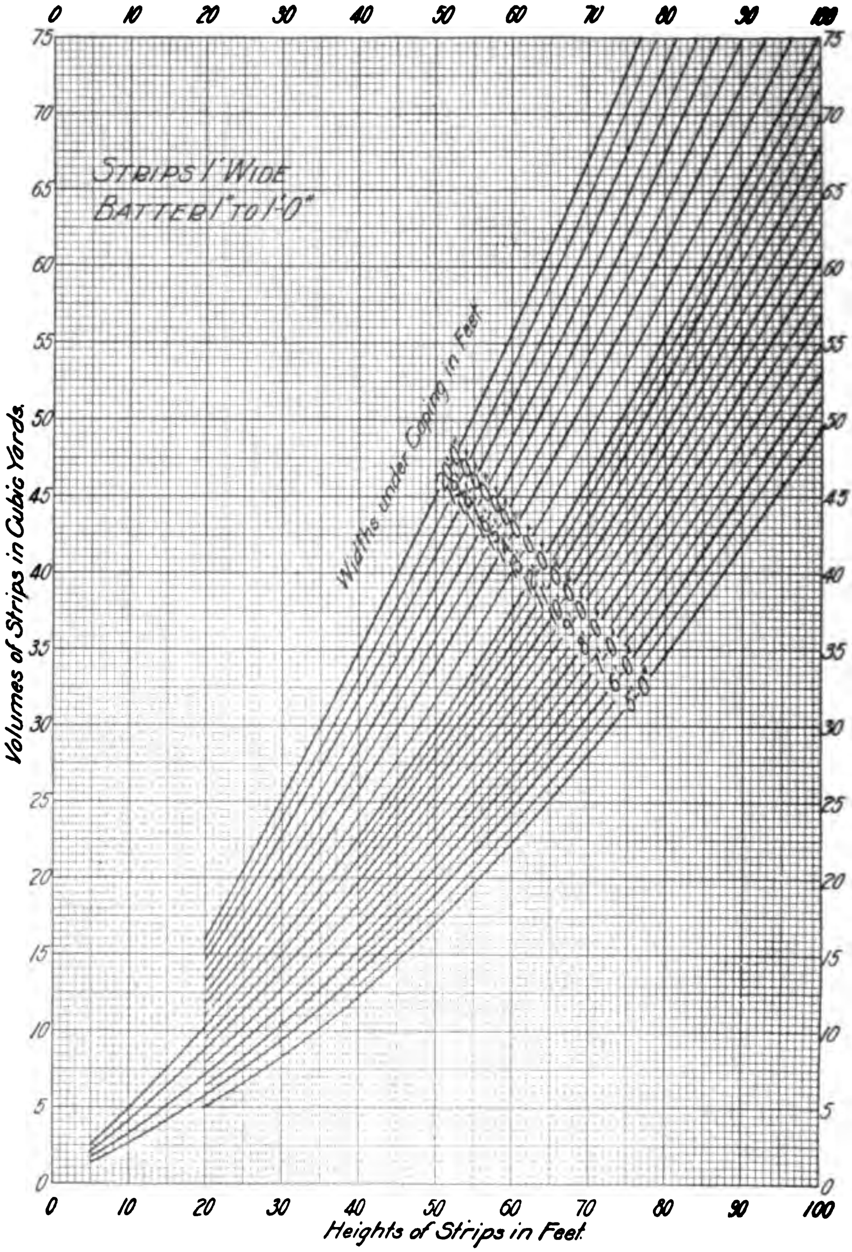


Fig. 56j. Volumes of Strips One Foot Wide in Middle Portions of Round-Ended Piers—Batter 1" to 1' 0".

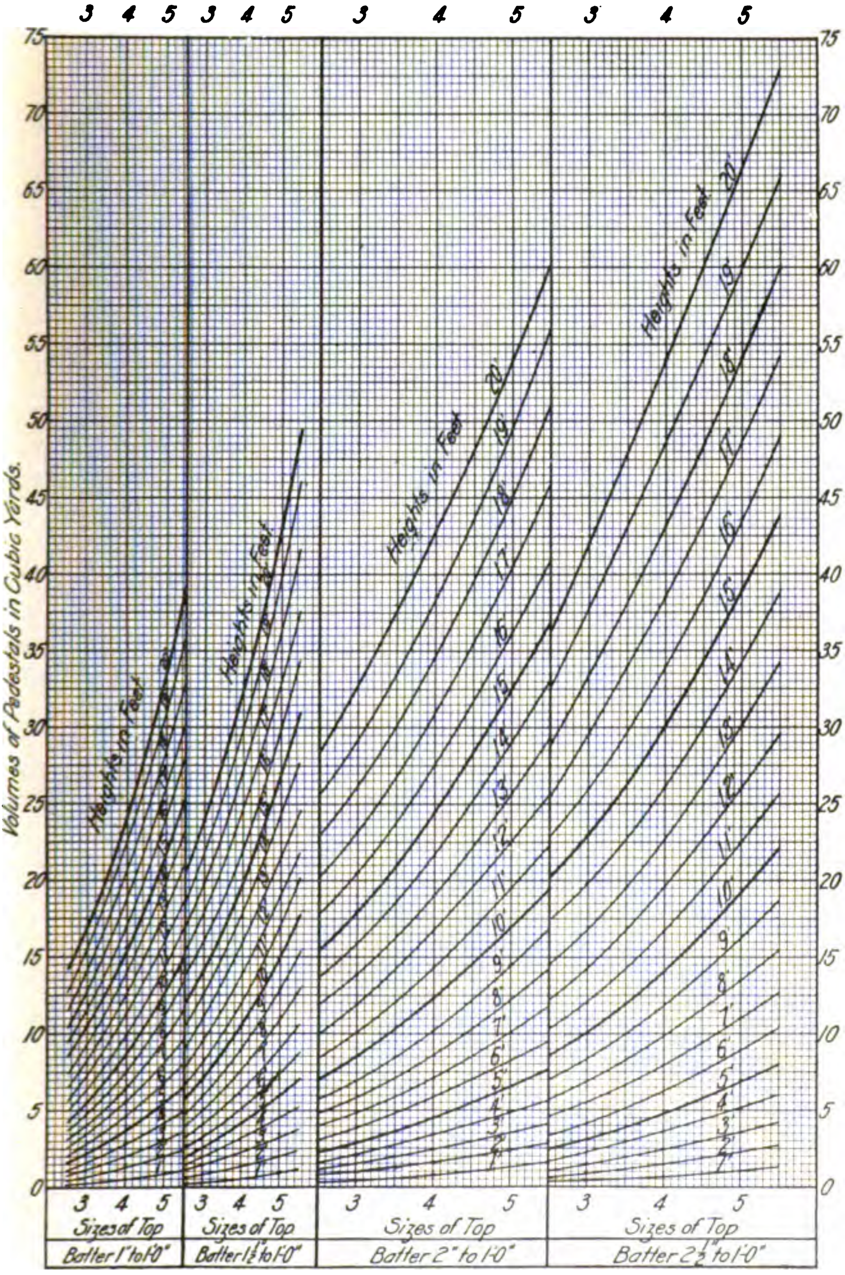


FIG. 56*k*. Volumes of Pedestals.

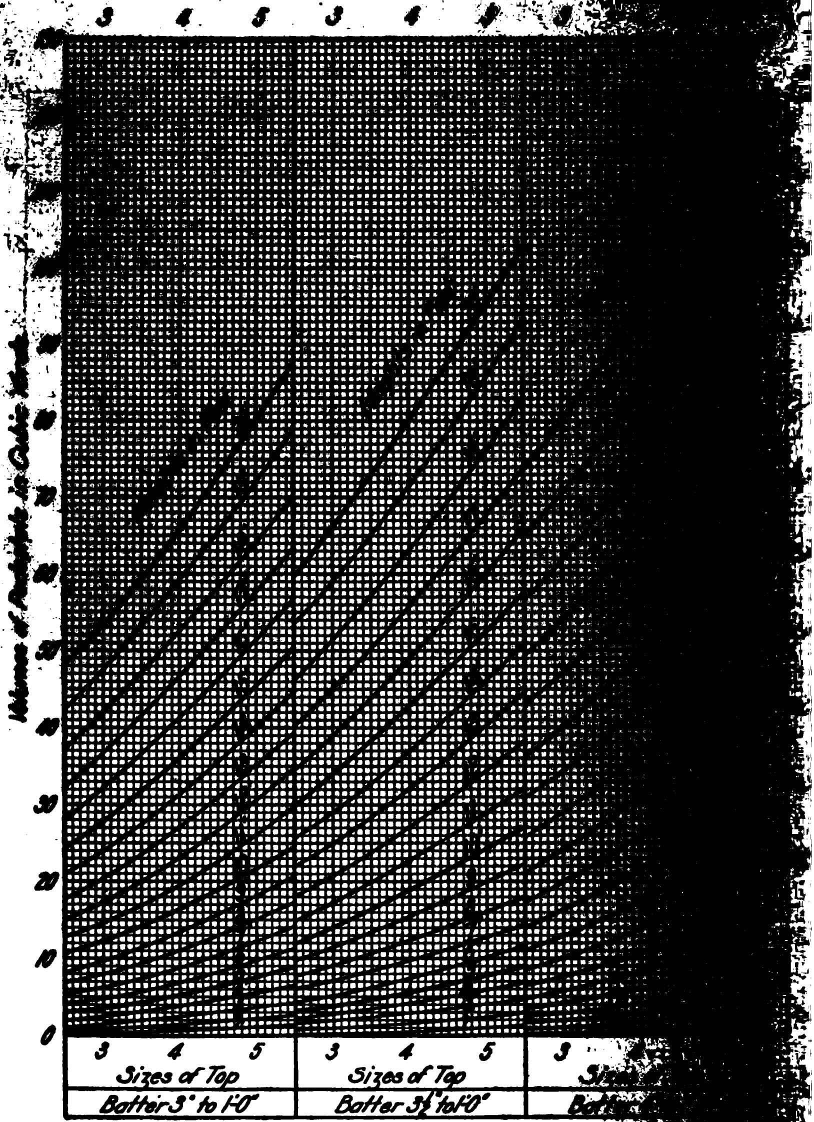
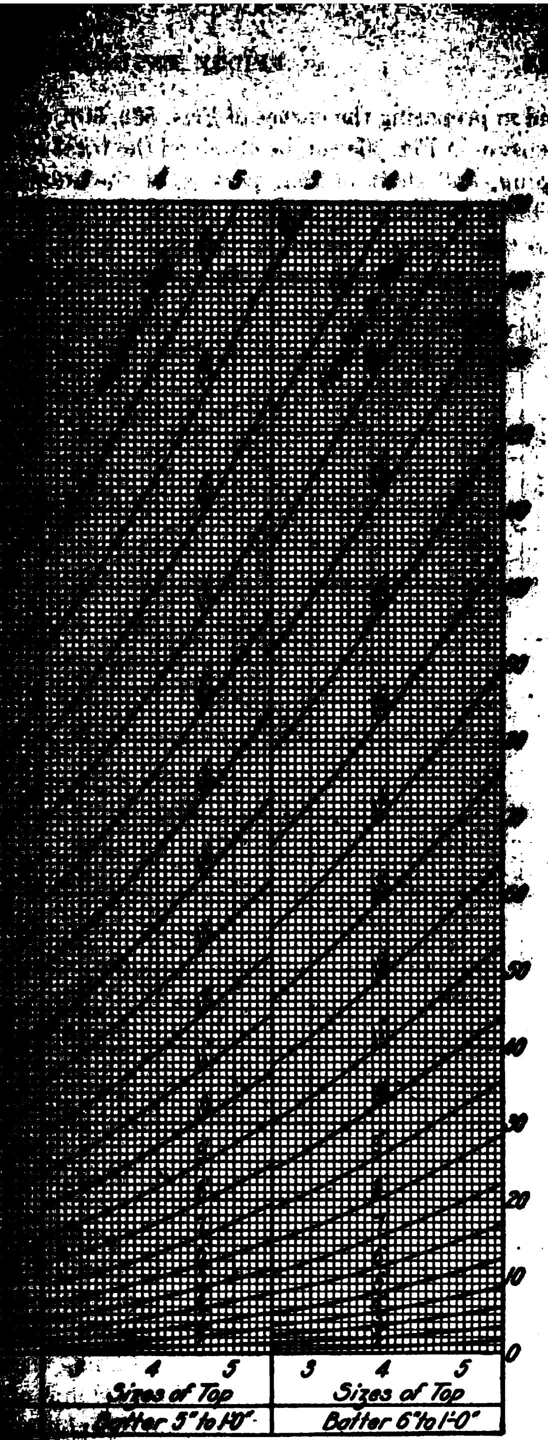


FIG. 56*l*. Volumes of Pedestals.

correct volume can be obtained by direct interpolation. an offset base, the figuring of the additional volume there more than a minute or two.

ABUTMENTS

The following method will give, with very little calcul ume of concrete or masonry in any wing-abutment for a way bridge. In Fig. 56*n* is presented a drawing of the



Volumes of Pedestals.

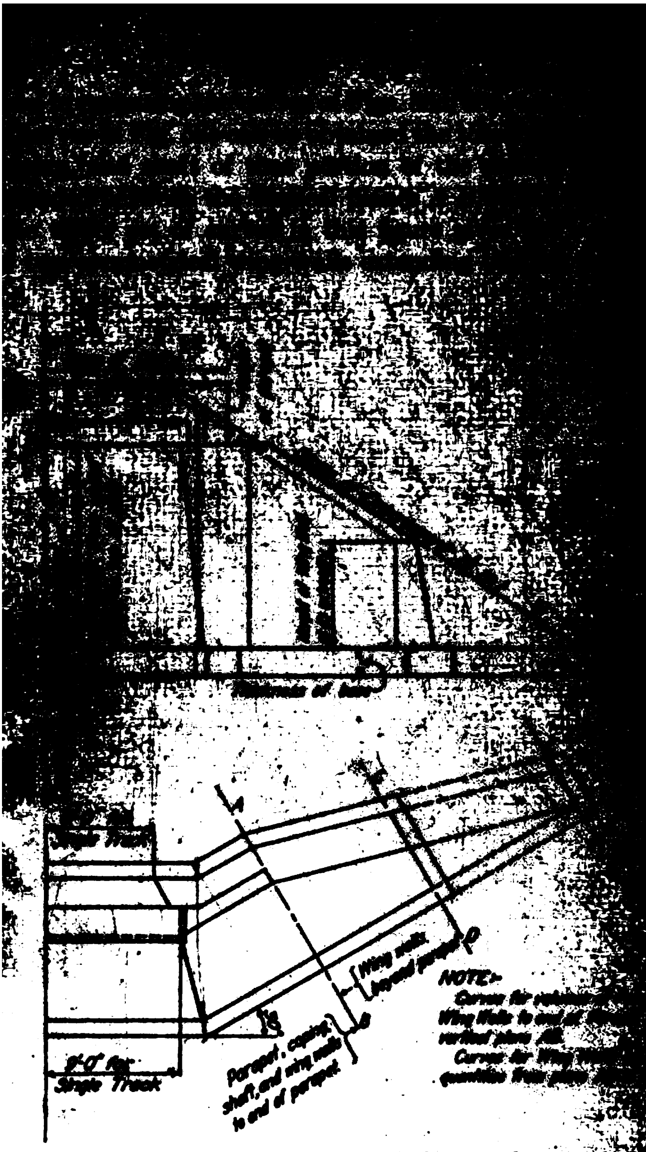


FIG. 56n. Typical Wing Abutment

ving-walls terminate before the top slope intersects
s to be made in accordance with the note at the
ase the two wing-walls are not symmetrical with
angent, each wall can be treated separately by
rom the curves by two. After ascertaining the
oping, parapet, and wing-walls, the volume of
hereto for the complete volume of the abutment.
ase is taken from the two sets of curves shown in
herein.

To obtain by means of these tables the volume

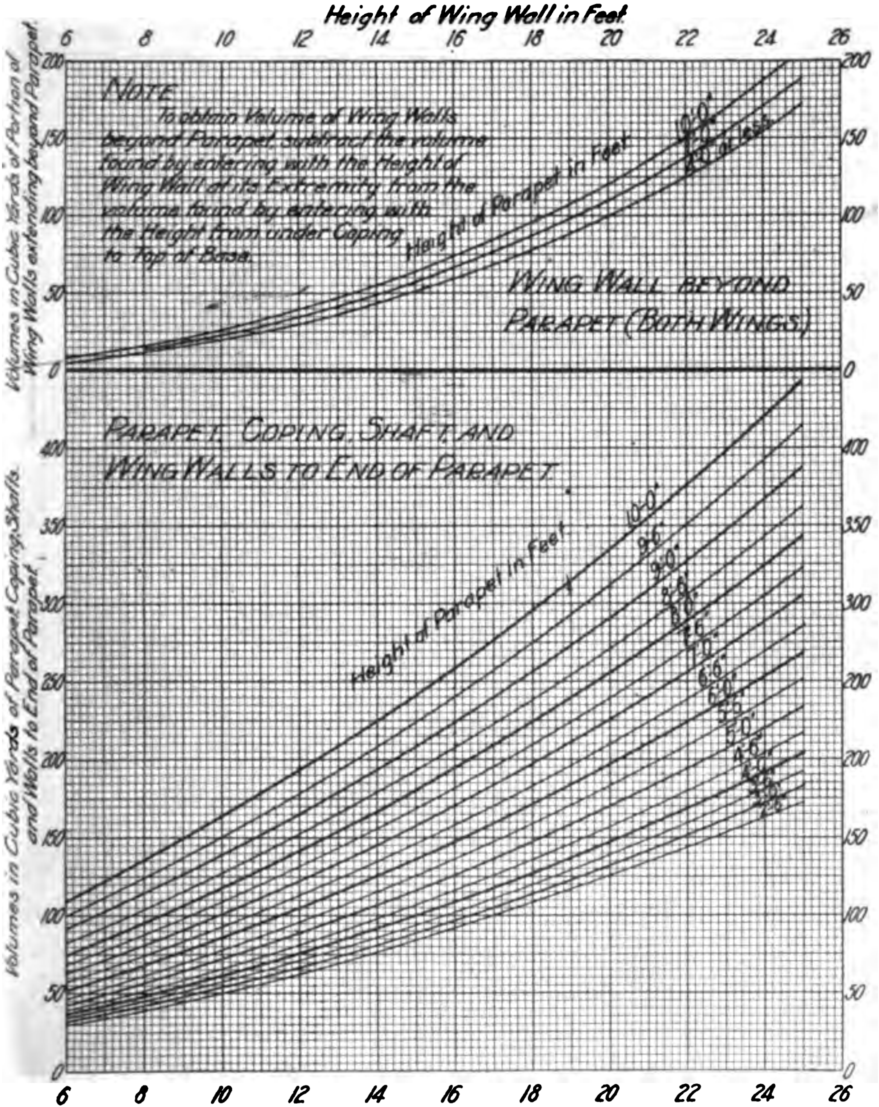
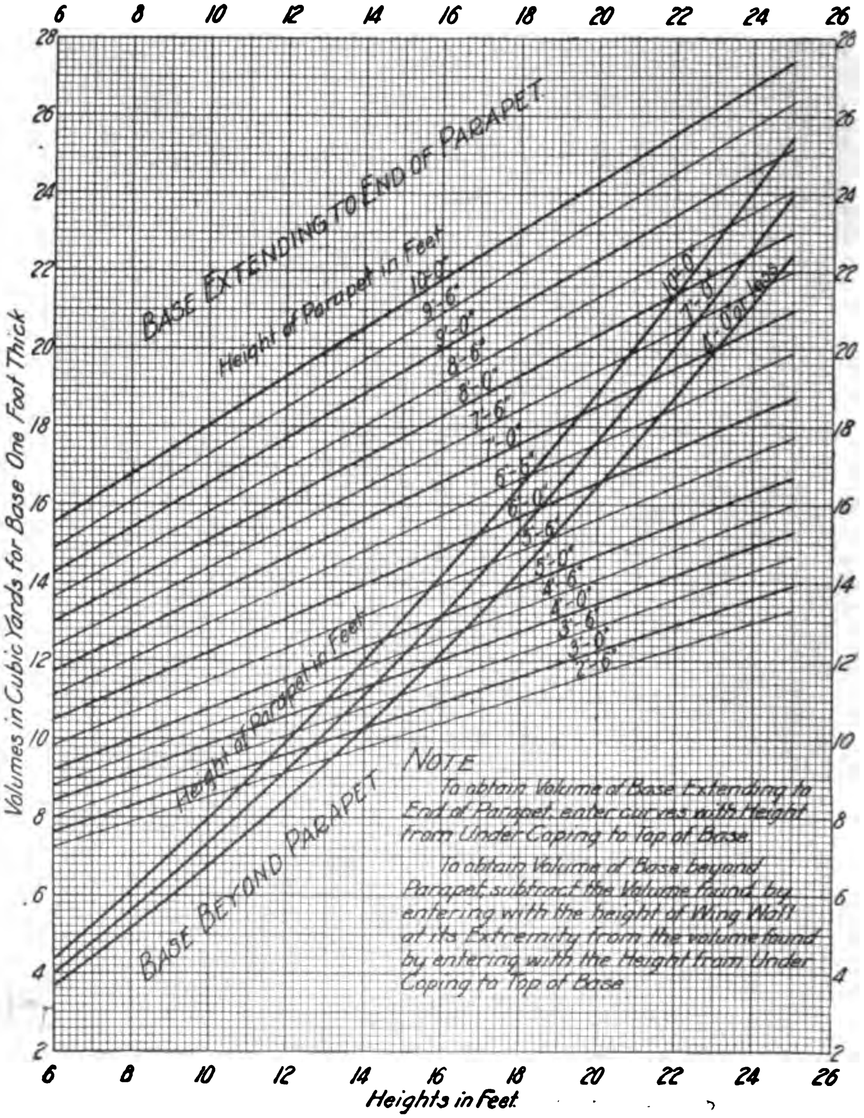


FIG. 56*o*. Volumes of Portions of Wing Abutments above the Base for Single-track Railway Bridges.

that is longer than that for a single-track railway bridge, it will be necessary to add the volume for the extra length of main wall. In double-track bridges the said extra length is generally thirteen or fourteen feet;



NOTE

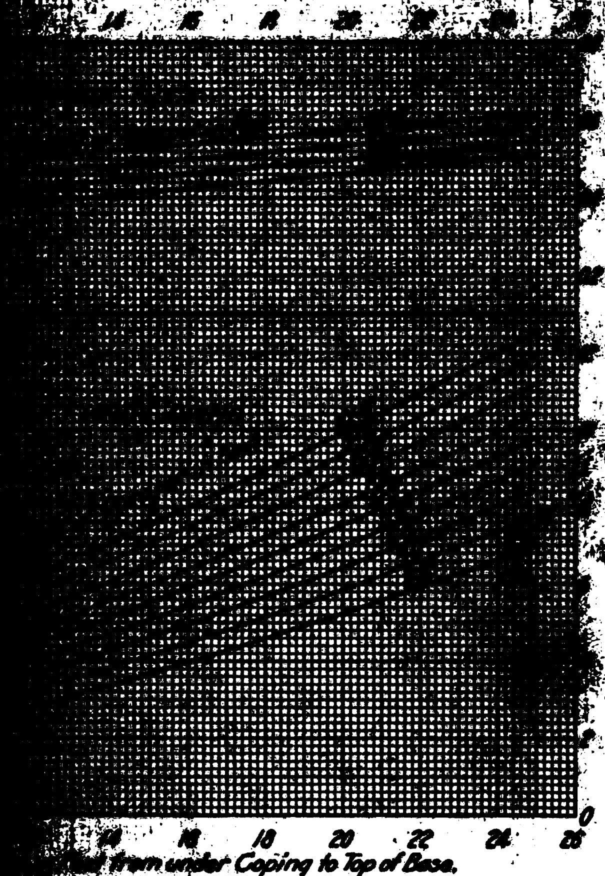
To obtain Volume of Base Extending to End of Parapet enter curves with Height from Under Coping to Top of Base.

To obtain Volume of Base beyond Parapet subtract the Volume found by entering with the height of Wing Wall at its Extremity from the volume found by entering with the Height from Under Coping to Top of Base.

FIG. 56p. Volumes of Bases of Wing Abutments for Single-track Railway Bridges.

and for a highway bridge it is equal to the clear roadway between trusses, minus fifteen feet. Fig. 56*q* gives the volume in cubic yards, including parapet, coping, and shaft, for each lineal foot of wall, also the volume of base in cubic yards per lineal foot of wall for each foot of its thickness

is to be multiplied by the height of the
is to be added to the volume found for the
and shaft per lineal foot; and the sum is



Feet Wide in Middle Portions of Wing Abutments
Railway Bridges.

al extra length of face wall. The product
age for the said extra length of face wall.

AINING WALLS

es of concrete and metal per lineal foot of
walls. The curves correspond to a toe-
line above them, and if a smaller toe-pres-
quantities given by the curves have to be
by the right line of the small figure in the
agram.

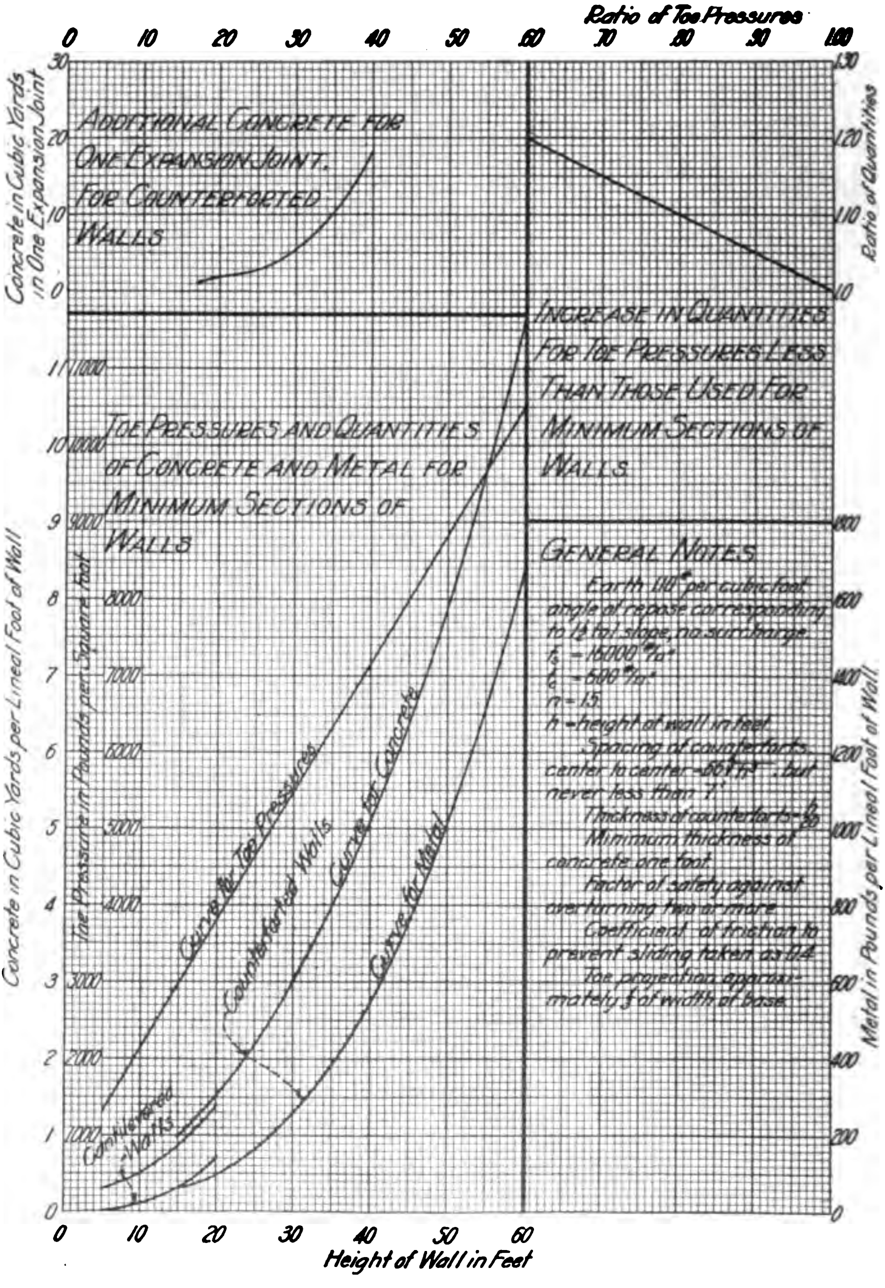


FIG. 56r. Quantities of Concrete and Metal per Lineal Foot of Reinforced-Concrete Retaining Walls.

per Lineal Foot of Plain Concrete Retaining Walls.

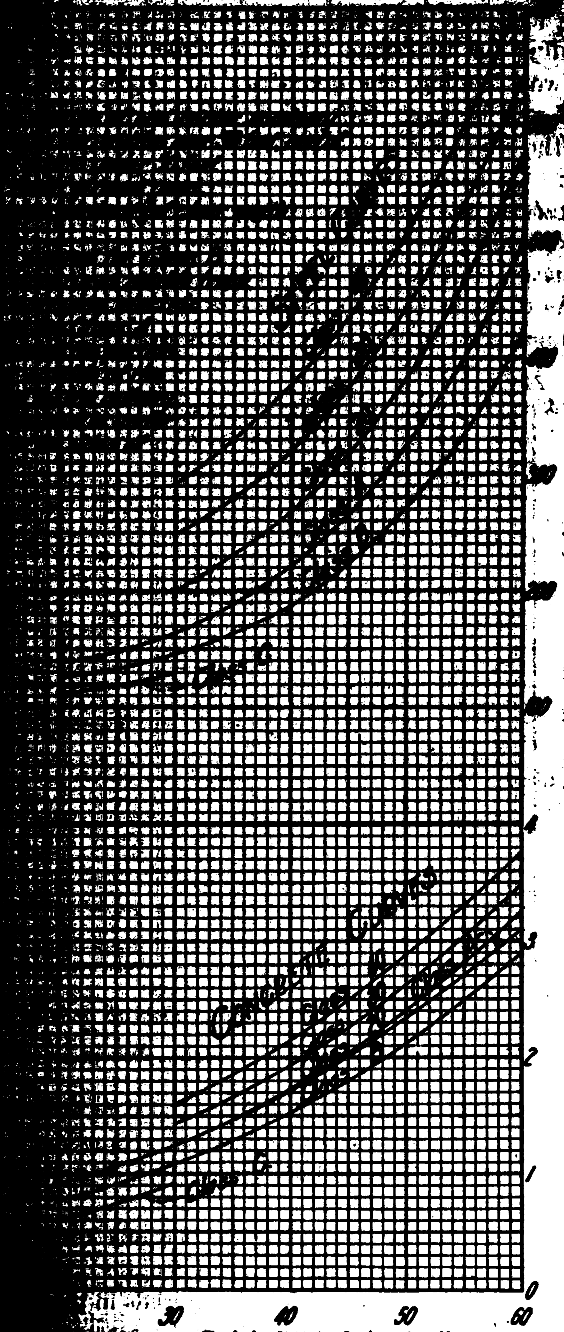
To show the application of the curves of
case in which the height of the wall is 30 feet
pressure 4,500 pounds per square foot. The
of concrete and 250 pounds of reinforcing metal,
The ratio of intensities is 45 ÷ 54 = 0.83. The
that the quantities have to be increased about
them [illegible] and 270 respectively.

Fig. [illegible] gives the quantities of concrete per
crete retaining walls. These curves were worked
as those for the reinforced walls, and their application

REINFORCED CONCRETE BRID

In Figs. 56t to 56dd, inclusive, are given diagrams
found, for all highway, electric-railway, and combined
tric-railway bridges built of reinforced concrete, the
and reinforcing steel required therefor. These curves
preliminary estimates only, as it is practically
diagrams that will furnish absolutely exact values for

Fig. 56t records, for various live loads and for
width from twenty (20) feet to sixty (60) feet, the
steel per lineal foot of bridge for the floor system,
its supporting cross-girders. A symmetrical cross-
with the floor slab supported on cross-girders which
two main girders. For narrow structures the girders
outside of the roadway; but for wide cross-sections
tilevered out beyond the main girders, the latter being
to centre approximately five-eighths (⅝) of the total
ture. The effect of varying this spacing within
found to be inappreciable. The cross-girders were
apart in all cases. The quantities in the floor systems
in certain cases for spacings of cross-girders ranging from
(14) feet; however, these differences were found to
but very slightly. For structures over thirty (30) feet
walks, one on each side, were adopted; but for narrower
way was assumed to occupy the entire width. Each
one-sixth (⅙) of the total width. In all cases Class B
was employed in figuring the sidewalk slab. No
used on the roadway in conjunction with concentrated
for widths under thirty (30) feet, only one truck was
greater widths two trucks were adopted. For electric-railway
however, Class A uniform live load was assumed on that
way outside of the twenty (20) feet occupied by the street
track structures were assumed in all cases, because a
crossing a highway bridge is quite rare. However, if



Concrete and Steel in Floor System

[illegible]

[illegible] and the cross-girders [illegible] It would be desirable in certain [illegible] girders and only the cross-girders [illegible]

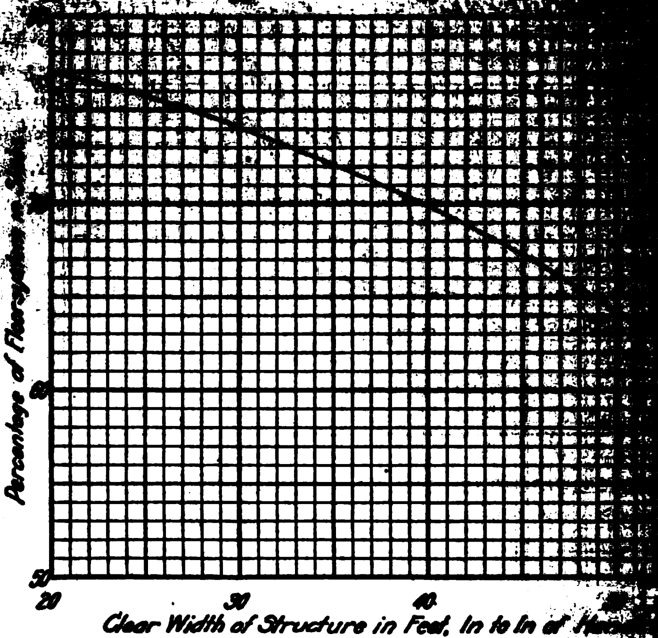


FIG. 56*u*. Reinforced-Concrete Bridges, Percentage of

This curve gives the percentage of the floor system will be found that for an economical arrangement, the layout with longitudinal girders only will be about design with cross-girders.

In Fig. 56*v* are recorded for various total lineal foot of girder, and for span lengths varying sixty (60) feet, the quantities of materials in the main concrete bridges. These quantities were computed freely supported, two-girder spans continuous over three or more girder spans continuous over four

spans being assumed of equal length. The dead load was taken equal to twice the live load, which is a fair average of the conditions for reinforced-concrete bridges; but a considerable change in this ratio will affect the quantities very little.

The section at the support is determined by moment or shear; and for any one layout the depths at all supports are made equal. The

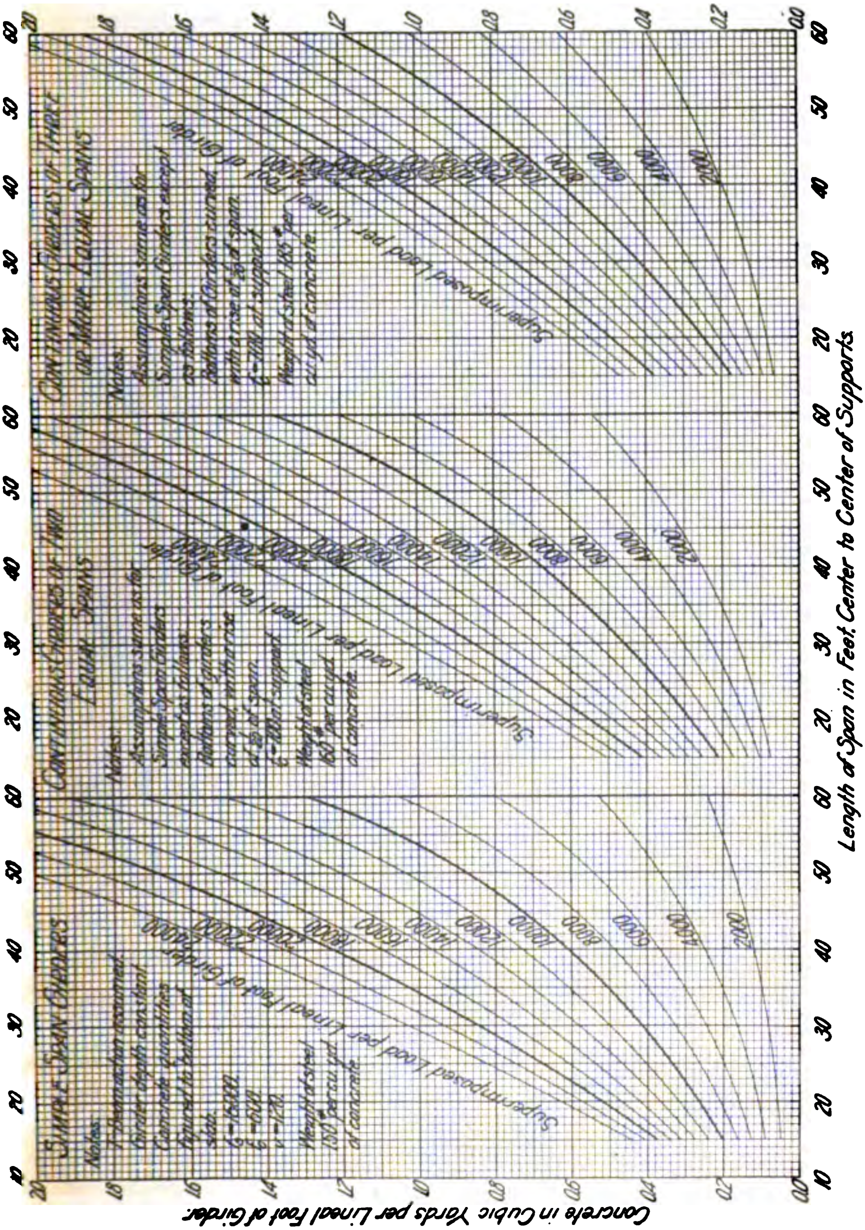


FIG. 56*v*. Reinforced-Concrete Girder Bridges, Concrete and Steel in Main Girders.

depth at the centre of span is assumed to be nineteen-twentieths of that at the support for continuous spans, in order to provide a slight upward curve in the bottom of the girder; while for simple girder spans the depth is kept constant throughout. Reinforcement is placed in the girder below the slab, so that at the support the beam is figured for the rectangular section beneath the said slab. T-beam action is assumed at the centre of span. The average thickness of slab was taken as eight (8) inches. The concrete quantities for the girders were computed from under side of slab to bottom of girders.

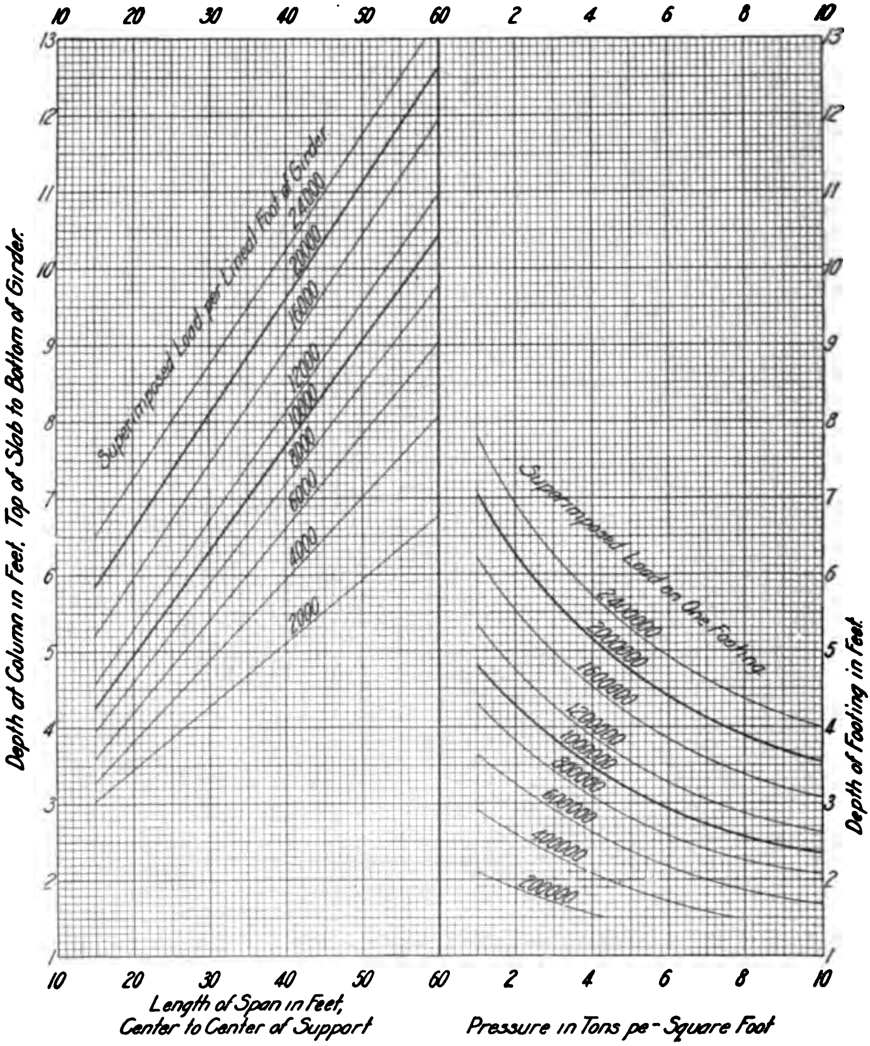


FIG. 56w. Reinforced-Concrete Girder Bridges, Depths of Girders and Footings.

It should be kept clearly in mind when using Fig. 56v that the diagram

lusive of that of the girder
foot of girder, as is the case in the
Chapter LV. The quantities, of course,
As it is somewhat difficult to approxi-
girders with sufficient accuracy, it saves
curves for the *superimposed* load.
able for layouts of continuous girders with
the variation is considerable. Where the
intermediate ones the actual quantities will
the curves, if the diagram be entered with
when the intermediate spans are the
will be smaller. For layouts in which the
small, the curves will give sufficiently
layout if they are entered with the

of girder and depth of column footing for
girder and total loads on footing. This
in determining the height of column
Fig. 56x.
various total superimposed loads and for
from ten (10) feet to one hundred (100) feet,
in one column; and Fig. 56y records the
per cubic yard of concrete. The section
square in all cases, and no transverse bracing
the column just under the girder was deter-
load, the gross section of the concrete

$- 20 \frac{l}{b}$, but not greater than 400 pounds

responds to an actual intensity on the con-
account of the reinforcement. The value of

20. This section was reinforced with one

steel area was used throughout the entire
a batter of one-eighth of an inch per vertical
concrete quantities were figured from top of
tudinal girder) to top of footing; but the
bars extending from the column into the
the reason for the large amount of steel

for various total superimposed loads on foot-
ranging from one (1) ton to fourteen (14)
of concrete required per column-footing
Each of these footings has a constant
sufficient to provide for shear by means

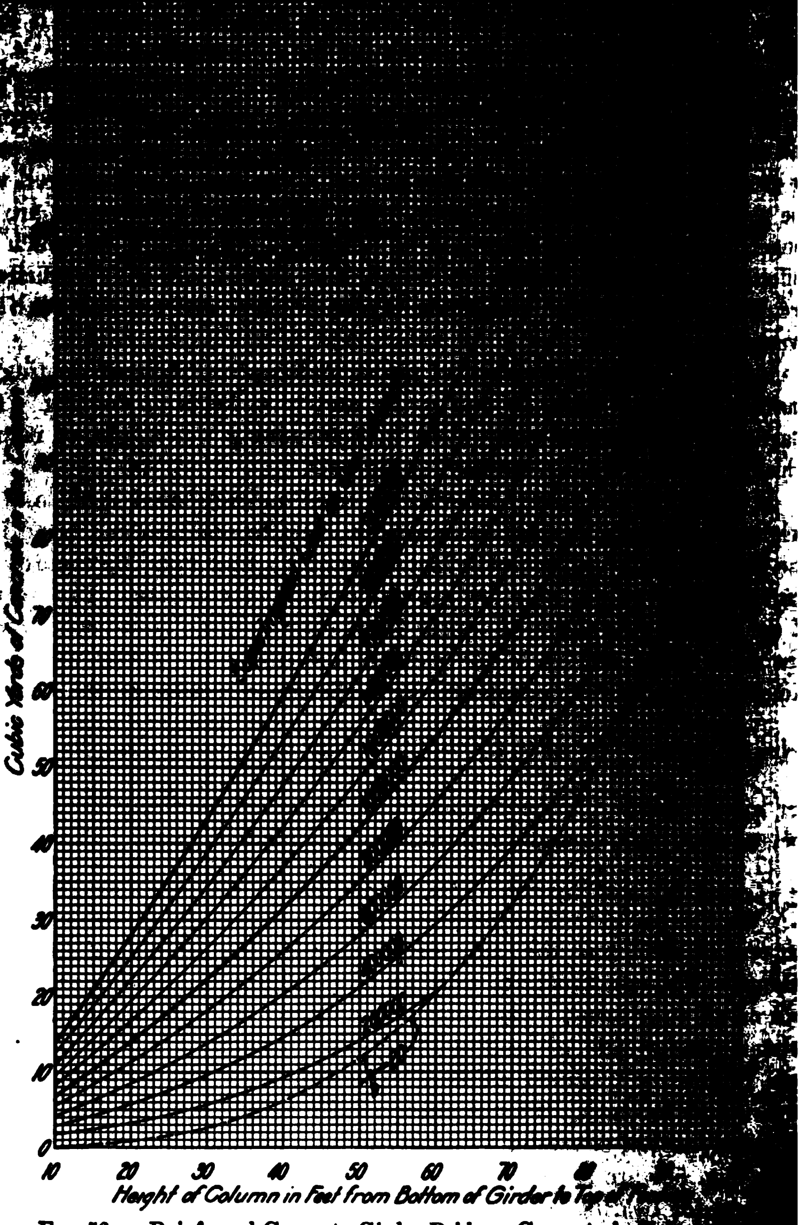


FIG. 56x. Reinforced-Concrete Girder Bridges, Concrete in

Concrete Bridges, Steel in Columns.

, the economic span length in a reinforced-
layout can be determined by the equation,

$$\left(0.3 + \frac{2,000}{w + 1,000}\right); \qquad \text{[Eq. 1]}$$

length from centre to centre of supports,
per lineal foot of girder,

any given case the height which is fixed,
to top of footing, height from grade to
underside of girder to top of footing, or
to bottom of footing, as the case may be.
range of length for which the quantities

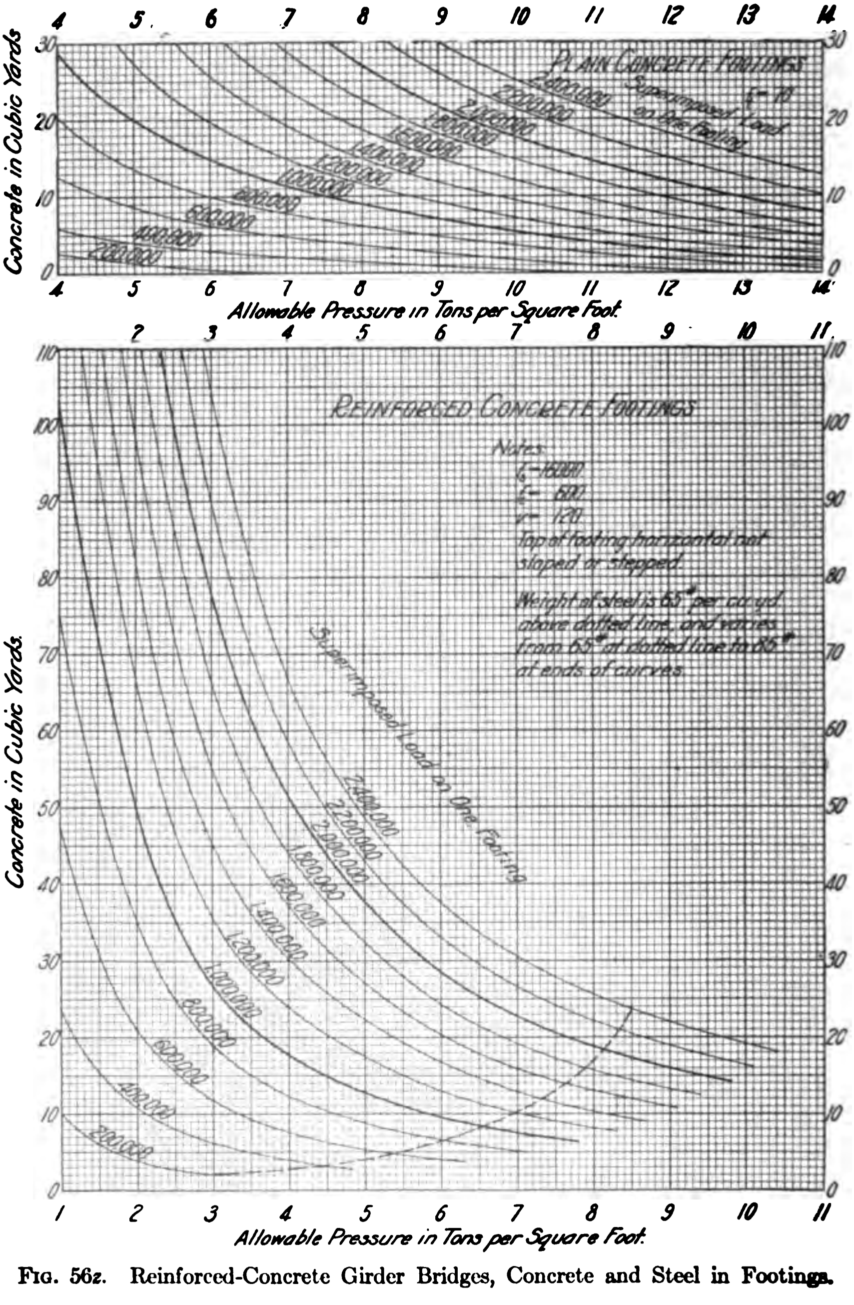
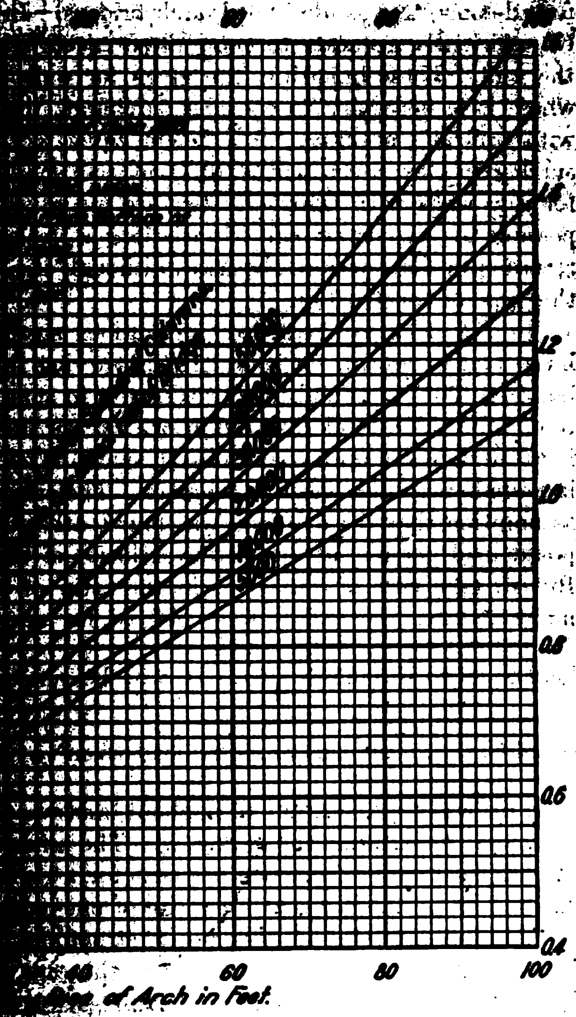


Fig. 56z. Reinforced-Concrete Girder Bridges, Concrete and Steel in Footings.

curve gives values a trifle greater than
are a minimum, since the use of
unit costs of the concrete.

the quantities of concrete per lineal foot
girders and columns of open-spandrel arches,
cubic yard of concrete. These quantities



Bridges, Concrete and Steel in Spandrel Girders and Columns.

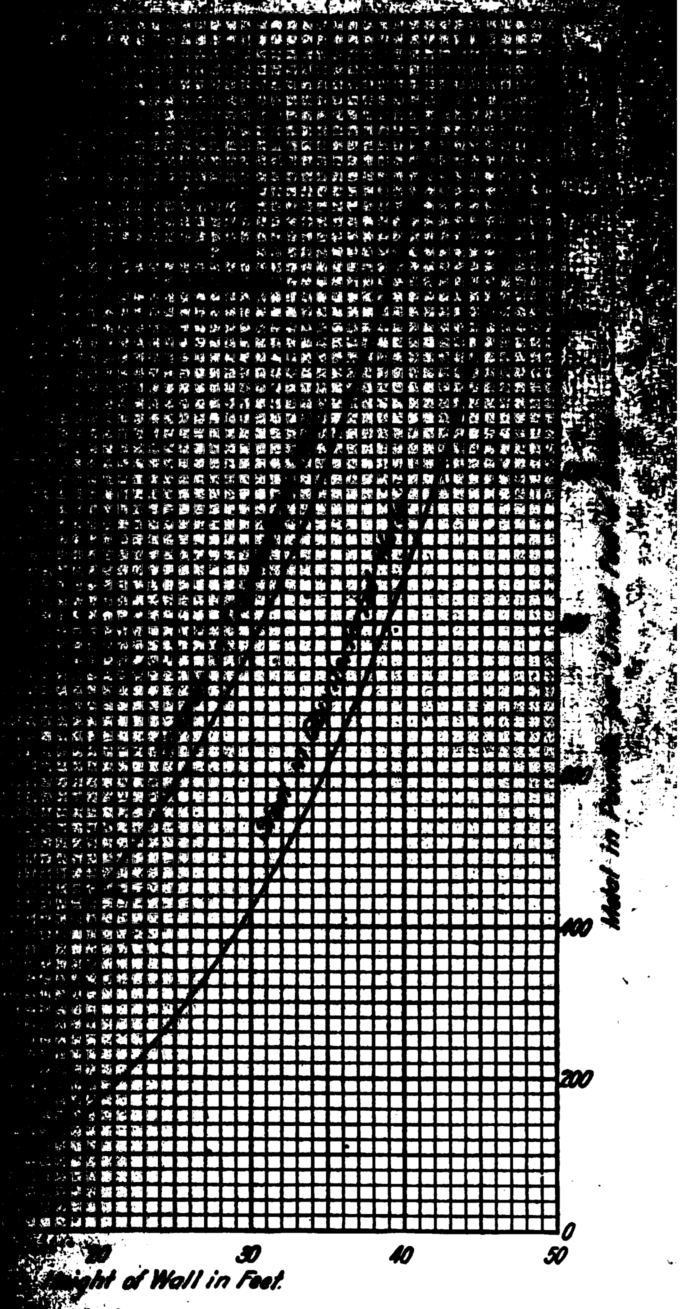
dependent to a large degree on the
treatment determines the proportions
However, the quantities are not
quantities in the structure; and, therefore,
will not be appreciable.

For barrel arches the cost of the structure above the rib will not be materially different from that of the ribbed spans, and consequently the quantities for the latter will be sufficiently accurate for barrel arches.

In Fig. 56*bb* are recorded, for the cantilever and counterforted types and for heights of wall up to fifty (50) feet, the volumes of concrete and weights of metal per lineal foot of structure in the spandrel walls of reinforced-concrete, spandrel-filled arch bridges. In nearly all cases it will be sufficiently accurate to enter these curves with the average height of the wall. These quantities are given for walls without surcharges; and where it is necessary to consider surcharge, the quantities can be taken with sufficient accuracy for a height equal to the actual height without surcharge plus seven-tenths (0.7) of the surcharge height. Quantities for side walls with transverse ties are not given, as it is practically impossible to do so on account of variations in the layouts; but the quantities recorded in Fig. 56*bb* can be used, although they are a trifle excessive for this type of construction.

In Fig. 56*cc* are recorded, for various superimposed total loads per lineal foot at crown, for span lengths varying from fifty (50) feet to two hundred (200) feet, and for ratios of rise to span length ranging from 0.1 to 0.5, the volumes of concrete in one rib per lineal foot of span required in the arch ribs of open-spandrel arch spans. The weights of steel are given in pounds per cubic yard of concrete. The curves were worked up on the assumption that the live load was four-tenths (0.4) of the total superimposed load per foot at the crown (exclusive of the weight of the rib itself). But to take care of variations in the ratio of live load to total superimposed load, the curves were platted for an equivalent superimposed load equal to $W\left(0.6+\frac{L}{W}\right)$. It will be noted that this expression is equal to the actual superimposed load when $\frac{L}{W}$ equals 0.4. The width of each rib was kept constant throughout, and was taken equal to or greater than the thickness at the springing. The amount of reinforcement used in each face varied from one per cent for a rise of one-tenth of the span to one-half of one per cent for a rise of one-half of the span.

The separate ribs of ribbed-arch structures must be braced together by cross-struts, except occasionally in the case of arches carrying heavy loads for which the ratio of rise to span-length is 0.2 or less. To determine whether bracing is required for such ribs, the load on the rib should be divided by the economic carrying capacity of the rib—determined from Fig. 56*dd*—thus giving the width of the rib; and braces should be employed whenever the ratio of unsupported length to width of rib is greater than twelve (12). In most cases this unsupported length is the distance from the crown to the springing, as the cross-girders usually brace the ribs effectively at the crown. The volume of the braces is more or less



Arch Bridges, Concrete and Steel in Spandrel Walls.

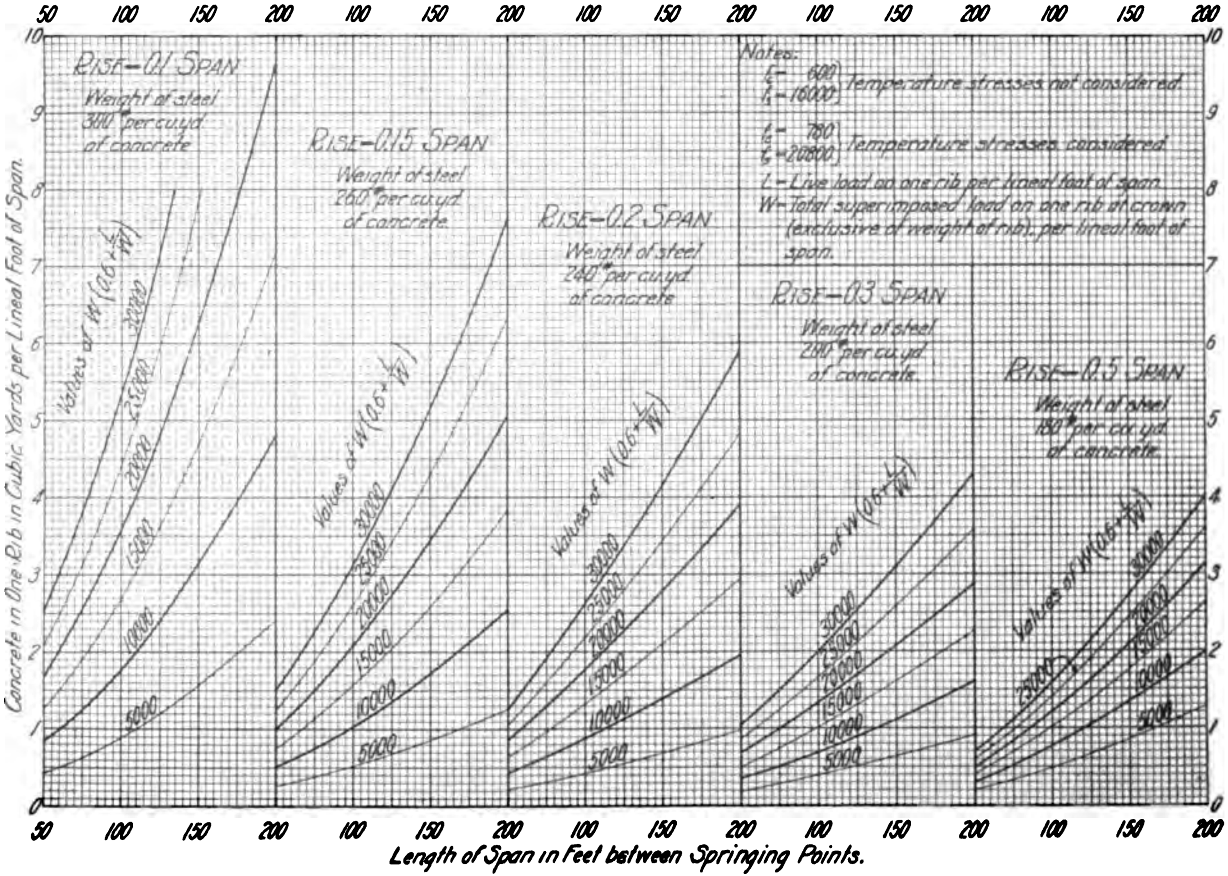


FIG. 56cc. Reinforced-Concrete Arch Bridges, Concrete and Steel in Arch Ribs.

FIG. 56dd. Reinforced-Concrete Arch Bridges, Concrete and Steel in Arch Barrels One Foot Wide.

[illegible]

[illegible] to which the live load [illegible] per foot at the crown [illegible] and the quantity CW ([illegible]) [illegible] of variations in the live load to total [illegible] the addition of the filling in the spandrel [illegible] noted that this expression equals the total [illegible] open-spandrel arch in which $\frac{L}{W}$ equals 0.4. [illegible] applicable to ribs of any width; and where the [illegible] they can be used to determine the most economic rib. [illegible] open-spandrel structures, it is thus possible to determine [illegible] ribbed type or the solid-barrel type is the cheaper, [illegible] that the ribbed type will require cross-braces. The [illegible] and 56*dd* are entirely consistent, those of the former [illegible] directly from those of the latter. A little extra steel [illegible] sides of the ribs of high rise.

It will be found that a considerable change can be [illegible] crete quantities of Figs. 56*cc* and 56*dd* by varying the [illegible] but the total cost of any rib will not be greatly affected [illegible] for the ribs in which the rise is one-half of the span, the [illegible] maximum carrying capacities of the ribs for the [illegible] ment adopted; but these capacities can be increased by [illegible] with but little loss of economy. However, this should [illegible] The minimum curves were determined by judgment. [illegible] the minimum plotted carrying-capacity of a rib, the [illegible] cubic yard of concrete can, of course, be reduced [illegible] value given on the diagram.

The two following examples will illustrate the use of [illegible] inclusive.

A. What is the economic span length for a [illegible] for a long structure to carry a double-track electric [illegible] live load at the middle of a creosoted-block-paved [illegible] figured to support Class A live loading, also two 8-foot [illegible] Class B live loading, the distance from ground to grade [illegible] permissible pressure on the foundation soil being 2.5 tons [illegible] and the depths of the foundations below ground level [illegible]

[illegible]

[illegible] Main Girders [illegible]

[illegible] structure):
[illegible] = 3.25 × 4,600 = [illegible] lbs.
[illegible] = [illegible] × 25 = 1,100 "
[illegible] = 20 × 75 = 1,500 "
[illegible] = 100 "
[illegible] = 2 × 400 = 800 "

[illegible] = [illegible],900 lbs.

[illegible] length of 60').
[illegible] structure):
[illegible] = 2 × 2,200 = 4,[illegible] lbs.
[illegible] = 41% = 1,[illegible] "
[illegible] = [illegible] × 111 = 2,670 "
[illegible] = [illegible]% = 840 "
[illegible] = 16 × 92 = 1,470 "
[illegible] = [illegible]% = 460 "

[illegible] = 11,900 lbs.

[illegible] = 28,800 lbs.

[illegible] (two girders per span) = 14,400 lbs.
[illegible] economic span,

$$[illegible]\left(0.3 + \frac{2,000}{14,400 + 1,000}\right) = 21.5.$$

[illegible] length of 20'.
[illegible] structure):
[illegible] = 40'
[illegible] = 2 × 2,650 = 5,300 lbs.
[illegible] = 47% = 2,500 "
[illegible] = 24 × 114 = 2,740 "
[illegible] = 36% = 990 "
[illegible] = 16 × 95 = 1,520 "
[illegible] = 36% = 550 "

[illegible] = 13,600 lbs.

[illegible] = 30,500 lbs.

[illegible] = 15,300 lbs.
[illegible] 56a) = 0.37 cu. yds.
[illegible] = 0.37 × 185 = 70 lbs.
[illegible] = 2 × 0.37 = 0.74 cu. yds.
[illegible] = 2 × 70 = 140 lbs.
[illegible] = 0.37 × 4,000 = 1,480 lbs.

Columns

Load on column from girder.................. = 21.5 (15,300 + 1,500) = 362,000 lbs.
Depth of girder (Fig. 56*w*)................. = 5.8′
Depth of footing (Fig. 56*w*)................ = 2.7′
Distance grade to top girder................. = 1.0′

Total................................ = 9.5′

Height of column......................... = 50′ − 9.5′ = 40.5′
Concrete in one column (Fig. 56*x*)................................ = 14 cu. yds.
Steel in one column (Fig. 56*y*).............. = 14 × 150 = 2,100 lbs.
Concrete in columns per lin. ft. of structure.. = 2 × 14 ÷ 20 = 1.4 cu. yds.
Steel in columns per lin. ft. of structure...... = 2 × 2,100 ÷ 20 = 210 lbs.
Weight of one column..................... = 14 × 4,000 = 56,000 lbs.

Footings

Load on footing.......................... = 362,000 + 56,000 = 418,000 lbs.
Concrete in one footing (Fig. 56*z*)................................ = 9 cu. yds.
Steel in one footing (Fig. 56*z*).............. = 9 × 65 = 585 lbs.
Concrete in one footing per lin. ft. of structure. = 2 × 9 ÷ 20 = 0.9 cu. yds.
Steel in one footing per lin. ft. of structure... = 2 × 585 ÷ 20 = 60 lbs.

SUMMARY OF QUANTITIES

Part of Structure	Concrete (Cu. Yds.)	Steel (Pounds)
Floor system	3.35	610
Girders	0.74	140
Columns	1.4	210
Footings	0.9	60
Total	6.39	1,020

B. For the same type of floor and loading as in the preceding reinforced-concrete trestle example, what will be the various quantities of concrete in the different parts (excluding abutments) of an arch bridge having a single, 150-foot-clear span (or 160′ between springings), of which the rise is 32 feet, the arch being open-spandrel?

Floor System

(See preceding problem)

Concrete per lin. ft. of structure................................ = 3.35 cu. yds.
Steel per lin. ft. of structure................................... = 610 lbs.

Spandrel Girders and Columns

Assume load on spandrel columns per lin. ft. of structure same as for main girders in the preceding problem........................ = 30,500 lbs.
Concrete per lin. ft. of structure (Fig. 56*aa*).......................... = 0.77 cu. yds.
Steel per lin. ft. of structure (Fig. 56*aa*)........... = 0.77 × 130 = 100 lbs.

Arch Ribs

Superimposed Load at Crown:

Dead Load (as for girder spans).............................. = 16,900 lbs.

Spandrel girders.................... = 0.77 × 4,000 = 3,100 "

Live Load (for 80′ span):

Class 25 (Fig. 6*h*)............... = 2 × 2,040 = 4,080 lbs.

Impact (Fig. 7*d*)............... = 36% = 1,470 "

Class A (Fig. 6*o*)............... = 24 × 108 = 2,590 "

Impact (Fig. 7*e*)............... = 28% = 730 "

Class B (Fig. 6*o*)............... = 16 × 90 = 1,440 "

Impact (Fig. 7*e*)............... = 28% = 400 "

Total live load.................................... = 10,710 lbs.

Total load per lin. ft of structure.............................. = 30,710 lbs.

Total load per lin. ft. of rib (two ribs per span).................. = 15,400 lbs.

Rise.. = 0.2 span

Concrete per lin. ft. of structure (Fig. 56*cc*)........... = 2 × 2.4 = 4.8 cu. yds.

Steel per lin. ft. of structure (Fig. 56*cc*).............. = 4.8 × 240 = 1,150 lbs.

Braces

Economic carrying capacity of rib (Fig. 56*dd*)......... = 1,300 lbs. per ft. width

Width of rib.................................. = 15,400 ÷ 1,300 = 12′

Unsupported length.................................... = 80′

Evidently no braces are needed.

SUMMARY OF QUANTITIES

Part of Structure	Concrete (Cu. Yds.)	Steel (Pounds)
Floor	3.35	610
Spandrel girders and columns	0.77	100
Arch ribs	4.80	1,150
Total	8.92	1,860

ARCH PIERS AND ABUTMENTS

Owing to the great number of the variables which affect the quantities of materials in the piers and abutments of reinforced-concrete arch bridges, it is entirely impracticable either to record the said quantities by diagram or to give any fairly approximate simple rule for their quick computation. Concerning this matter the author speaks advisedly; for he personally wasted a whole week of ten or twelve working hours per day in trying to establish a formula therefor, involving the following variables: length of structure, width of deck, average live load (including impact) per square foot of floor, average ratio of rise to span, average height of piers and abutments, average intensity of pressure on foundations, average ratio for all piers of the inequalities (greater than unity) of the two

adjacent clear span-lengths, average length of span for entire bridge, number of spans in structure, and average for all piers of the vertical distances from the lowest part of base to the point of application of the resultant of the two thrusts. These variables were properly taken care of in the tentative equations; and approximately correct rules for their methods of variation were established, as hereinafter indicated. The author had at hand properly digested and tabulated data for eight large arch structures; but, unfortunately, there were other variables than the preceding ones involved in their designing which prevented any satisfactory systemization—for instance, one bridge was built as light as the engineers' consciences would allow in order to meet a fixed appropriation, while another was made very massive for æsthetic effect to suit the requirements of a client; two bridges had ice-breaks, while the others had none; some of the decks were cantilevered out beyond the piers, while the others were not; some arches were ribbed, while others were solid-barrelled; some structures with unequal adjacent spans had their points of springing adjusted so as to keep down the overturning moments on the piers, while in others the springing points on each pier were at the same elevation; one bridge alone had a double-deck; and one structure had two abutment piers, while none of the others had any. As a climax to all these variations were the personal equations of the various computers—and these in reinforced-concrete work are by no means inconsiderable, varying often by many per cent—but (worse yet!) the fact that the mental condition of the individual computer changes from time to time has an influence on concrete quantities that is far from being negligible. Much to his regret, the author had to abandon his intention of preparing two or three general formulæ for concrete quantities in the piers and abutments of the various kinds of reinforced-concrete arch bridges. Such a set of equations would have rounded out in fine shape the tabulated and diagrammed records of quantities of materials in bridges given in this treatise. To this extent the author's work may, perhaps, be claimed to be incomplete; but as it is necessary at times for an engineer to make a hurried estimate of cost of a proposed reinforced-concrete arch bridge, some means of ascertaining, at least approximately, the quantities in piers and abutments is a necessity. Hence the author will record here a few data based upon a function that he has evolved and has termed the "Volume of Layout," which consists of the product of the area of the profile (measured vertically between the grade of the floor and the periphery formed by connecting with right lines the lowest parts of adjacent pier foundations, and horizontally between the inner faces of the abutments) by the width of the deck.

In Table 56a are recorded for seven reinforced-concrete arch bridges the following functions: Length in feet of structure between inner faces of abutments; clear width of deck in feet; average height in feet of all the piers and the abutments; average live load, including impact, in

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Colorado River Bridge, Austin, Tex.	942	46	[illegible]	[illegible]	10.0	0.16	1.00	111	[illegible]	8	[illegible]	[illegible]	7,700	[illegible]	[illegible]	[illegible]
Design for Bridge at Lafayette, Ind.	710	56	61	90	4.8	0.155	1.00	128	[illegible]	5	[illegible]	[illegible]	[illegible]	7.0[illegible]	7.[illegible]	[illegible]
Design for Swope Park Bridge, Kansas City, Mo.	580	60	78	120	7.2	0.21	1.25	100	[illegible]	5	[illegible]	[illegible]	7,[illegible]	7.[illegible]	7.2	[illegible]
Arkansas R. Bridge, Tulsa, Okla.	1,400	38	42	130	12.0	0.136	1.00	71	24	18	[illegible]	[illegible]	4,[illegible]	[illegible]	[illegible]	[illegible]
Fifth St. Bridge, Dayton, O.	611	57	43	170	6.0	0.10	1.00	81	[illegible]	7	[illegible],370	[illegible]	7,[illegible]	[illegible]	[illegible]	[illegible]
Webster St. Bridge, Dayton, O.	351	57	38	170	5.5	0.112	1.00	111	[illegible]	8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

pounds per square foot of floor; average
square foot of foundation; average of all the
in the arches; average for all piers of the
adjacent clear span-lengths; average of all the
average of the vertical distances in the various piers
the point of application on the vertical axis of the
number of spans in structure; approximate area in square
bounded by the grade line of floor, the periphery of
inner faces of abutments; the "Volume of the Layout"
found by multiplying the last-mentioned area by the
the total volume of concrete in all the piers and one
the percentage which this last quantity is of the "V
and the same percentage corrected so as to agree
that the volume of the one abutment included is equal
volume of all the piers. In the last column are
remarks recording various special features of the
Attention is called to the fact that in the Tulsa Bridge
percentage covers the exclusion of the two abutment-
the record for this structure on the same plane as
functions of these abutment-piers are to prevent
entire bridge in case of a washout of any pier, and to
sible future construction of a movable span. Their
structures where a washout is possible is a wise
one should not, on account of having used them,
neglecting to make each pier and each abutment just as
ticable against being undermined.

The method of employing Table 56*a* for any
follows:

First. Prepare a true-scale profile of the crossing,
line, the ground line, and the inner faces of the abut
on it a foundation line, indicating, as well as can be
depths to which the piers and abutments must go.

Second. Calculate roughly the area included between
foundation profile, and the face lines of abutments,
the clear width of roadway, so as to obtain the "Volume

Third. Determine which of the seven bridges in
ditions most nearly agreeing with the one in question in
character of construction, and take its recorded value of
together the values of v and P' thus found and divide
one hundred. The result will be the total volume in
the piers and one abutment that has the same volume
the volumes of all the piers. If there be two such
found is to be multiplied by the ratio $\frac{n+1}{n}$, where
spans in the proposed bridge. If the abutments are

[illegible] for all the piers [illegible]

[illegible]

[illegible] result found by the ratio [illegible] and to

[illegible] for the two abutments, which can be

[illegible] explained later.

[illegible] any abutment-piers in the structure, each

[illegible] about twice the volume of the average ordi-

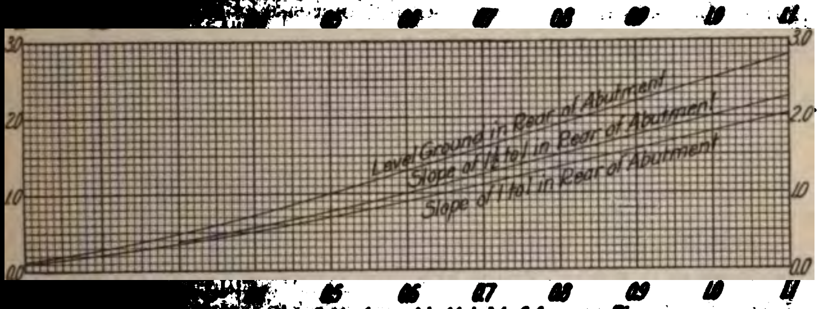
[illegible] are n' such abutment-piers, the value of $\frac{vP'}{100}$

[illegible] multiplied by the ratio $\frac{n + n'}{n}$ in order to deter-

[illegible] in all the piers and one similar-sized abutment.

[illegible] of piers and abutments for the various heights

[illegible] because much will depend upon the natural



[illegible] Arch Bridges, Approximate Ratios of Volumes of [illegible]butments and Average Piers.

[illegible] rear of the latter. For piers and abutments [illegible] of one and a half to one, the abutment will [illegible] of the pier; while if the ground be level, it [illegible] half times as much. For piers and abutments [illegible] of the abutment will be about sixty (60) per [illegible] the rear slope of the ground is one and a half [illegible] per cent when it is level. In order to facili-[illegible] approximate volumes of the abutments, Fig. [illegible] In using it one should not forget that it is, of [illegible]proximate, but sufficiently accurate, however,

[illegible] relate to any crossing for which no definite [illegible] been made. After these features of the [illegible] settled, a more accurate estimate of the total [illegible] can be obtained by modifying the value [illegible] before multiplying it into $\frac{v}{100}$. The said

[illegible] to the proposed structure.

Height

The percentage p' for a change in height is [illegible] ing equation,

$$p' = P' \left(\frac{h}{H}\right)^{\text{[illegible]}}$$

Live Load

As the dead load does not increase quite as [illegible] and as the section of the pier does not increase as [illegible] upon it, the value of p' for a change in the live load [illegible]

$$p' = P' \left(\frac{w}{W}\right)^{\text{[illegible]}}$$

Intensity of Pressure on Found

As it is only the base of the pier which is [illegible] the value of p' with changing foundation loading [illegible] about as given thus,

$$p' = P' \left(\frac{I}{i}\right)^{\text{[illegible]}}.$$

Ratio of Rise to Span-Length

It is difficult to say how the change in the [illegible] span-length will affect the volume of the piers, but the [illegible] that the following equation will provide fairly well for the [illegible] variation:

$$p' = P' \left(\frac{R}{r}\right)^{\text{[illegible]}}.$$

Inequality of Adjoining Span-Lengths

The effect of this factor will depend on the [illegible] of the two spans on each pier. If these be kept at [illegible] value of p' will be given approximately by the [illegible]

$$p' = P' \frac{r'}{R'};$$

for this structure, and the other

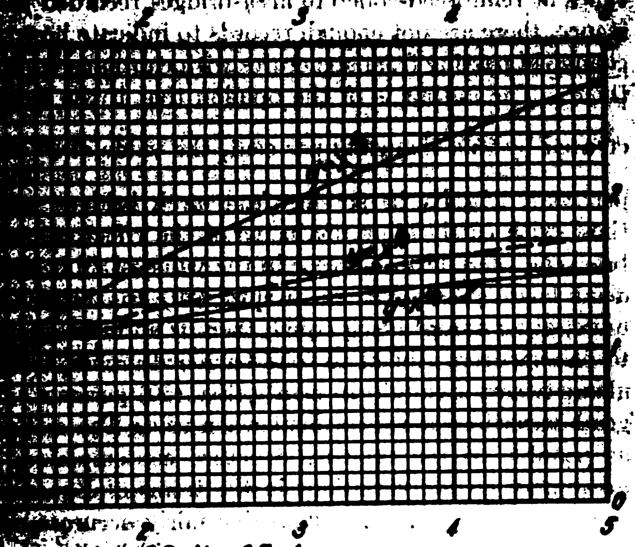
of the first power and

sidered.

the Span-Length

total volume of piers and abutments will

clear opening adopted, but not very greatly



Arch Bridges, Exponential Curves for Reduction Equations.

greater span-length the number of piers is de- pier is increased. The effect of variation will by the equation,

$$p' = P'\left(\frac{S}{s}\right)^{\frac{1}{8}}. \qquad \text{[Eq. 8]}$$

Arms of Resultant Thrusts

too great a difference between the values ariation will be given with sufficient accuracy

$$= P'\left(\frac{t}{T}\right)^{\frac{1}{8}}. \qquad \text{[Eq. 9]}$$

[illegible]

[illegible] almost unnecessary to [illegible]

of $\frac{P}{P'}$, given by Equations 2 to 9 inclusive, will

which to multiply the value of P' taken from Table

In order to determine readily the values of $\frac{P}{P'}$ in

clusive, Fig. 56ff has been prepared Entering the
with the ratio of the factors under consideration and
upward to the curve representing the exponent of
value is read at the left-hand margin.

It is to be regretted that there are not more
types of reinforced-concrete arch-bridges recorded in
stance, there are not enough records to indicate how
change in passing from structures with cantilevered
them. The author is of the opinion that if the

creased by this change m per cent, the value of P'

per cent. Again, in passing from arch bridges
those with earth-filling, exclusive of the effect of
brackets, there is an increase in the value of P' because
dead load—possibly from twenty (20) to thirty (30)
more, other things being equal, there is an increase in
to passing from ribbed to solid-barrelled arches,
about twenty-five (25) to nearly fifty (50) per cent.
great variations it is expedient when using Table 56a
as possible to the type of structure contemplated,
great may be the variations in the terms of Equations
because all the said equations give fairly accurate results
values of the corresponding terms are widely divergent.

In respect to what is the proper amount of reinforcing
yard of concrete to allow for the piers and abutments of
crete arch-bridges, there is a very wide range, depending
lightness or the massiveness of the construction, the
greater being the proportionate quantity of the metal.
ing solid-barrelled arches, twenty (20) pounds per cubic yard
while for ribbed arches, the steel should be taken at from
ninety (90) pounds per cubic yard, with an average of
pounds. The lower of these values should be used for
tion, while the upper one should be adopted for light
sections have to be well reinforced for bending.
will vary from twenty (20) to seventy (70) pounds
mass-abutments with small wing walls, the lower
while for the same type of abutment with large
having from one-quarter to one-half of the volume

(50) pounds should be assumed; ... (70) pounds per cubic yard will be

... of finding the volumes of piers and abutments ... any consulting engineer, in regard to struc... specifications and according to his individual ... and detailing, by analysing the records of some ... therefrom a table similar to Table 56*a*; and ... for the values of P' in order to obtain close ... Equations 2 to 9 inclusive, of this chapter, or ... similar but slightly different equations that will ... his individual ideas of the methods of volume

... yet had occasion to design a reinforced-concrete ... is unable to give here any data in regard to such ... perfectly practicable to record all the quantities of ... the same way as herein explained for high... highway-and-electric-railway bridges of rein... and to use the record in the manner described. ... number of reinforced-concrete railroad bridges have ... table of adequate size and scope similar to Table ... records of such structures should be made ... benefit of the engineering profession in general. ... for some professor of engineering who specialises ... almost certain that he would meet with no diffi... necessary data from the bridge specialists and the

... to apply Table 56*a* and Equations 2 to 9, in... an example will now be given.

... 1,600 feet long between inner faces of abut... between hand-rails of 50 feet, an average height of ... to 75 feet, a live load (including impact) of ... an intensity of pressure on foundations of ... rise to span of 0.2, an average of all the ratios ... equal to 1.2, an average clear span of 125 feet, ... thrust equal to 45 feet, the number of spans ... there are cantilever brackets, that the arch is ... earth fill), and that the heights of the abut... with a slope of earth about one and a half ... abutment and one that is nearly level behind

... layout is 1600 × 75 = 120,000 sq. ft., and ... 120,000 × 50 ÷ 27 = 222,200 cu. yds. The ... nearly resembling the one proposed is the ... of P' is 6.0.

Substituting in Equations 2 to 8, inclusive, gives the following factors:

$$\frac{p'}{P'} = \left(\frac{75}{62}\right)^{\frac{1}{4}} = 1.05$$

$$\frac{p'}{P'} = \left(\frac{140}{165}\right)^{\frac{5}{8}} = 0.90$$

$$\frac{p'}{P'} = \left(\frac{16.0}{5}\right)^{\frac{1}{3}} = 1.49$$

$$\frac{p'}{P'} = \left(\frac{0.16}{0.20}\right)^{\frac{1}{3}} = 0.93$$

$$\frac{p'}{P'} = \left(\frac{1.2}{1.0}\right)^{\frac{1}{3}} = 1.07$$

$$\frac{p'}{P'} = \left(\frac{111}{125}\right)^{\frac{1}{3}} = 0.97$$

$$\frac{p'}{P'} = \left(\frac{45}{40}\right)^{\frac{1}{3}} = 1.04$$

Multiplying these values together we have

$$p' = 1.415\,P' = 1.415 \times 6.0 = 8.49$$

$$\therefore v' = 222{,}200 \times 8.49 \div 100 = 18{,}900 \text{ cu. yds.}$$

On account of the irregularity of both abutments, this amount has to be multiplied by $\frac{12-1}{12}$ in order to find the contents of the eleven piers alone, making

$$18{,}900 \times \frac{11}{12} = 17{,}300 \text{ cu. yds., or } 1{,}580 \text{ cu. yds. per pier.}$$

The ratios of heights of abutments and average pier are $\frac{65}{75} = 0.87$ and $\frac{25}{75} = 0.33$. Referring to Fig. 56*ee*, we find for the large abutment a ratio of 2.1 and for the small one a ratio of 0.44, making a total of 2.54 for the two abutments; hence their combined volume is

$$1{,}580 \times 2.54 = 4{,}010 \text{ cu. yds.}$$

Adding this to the 17,300 cubic yards found for the eleven piers makes a grand total of

21,310 cu. yds.

This chapter was the last one of the book to be completed, because the quantities of materials for reinforced-concrete bridges were not figured until after the MS. of all the other chapters had gone to press; and this question of quantities for piers and abutments was the last one of all to be solved. It had been considered not only by all of his assistants, but also

[illegible] structures [illegible] purposes he evolved the method herein [illegible] the diagrams of Figs. [illegible] to [illegible] determining approximately the quantities [illegible] reinforced-concrete bridges will be found [illegible]. In the author's opinion, they [illegible] preliminary estimates of cost; but [illegible] should never be considered safe unless [illegible] made special computations and [illegible] and formulæ, however, should be found serviceable [illegible] check on the accuracy of all the quantities [illegible] in detail for contractors' bidding figures.

[illegible] that the establishing of fairly accurate data for [illegible] for reinforced concrete bridges has, during the [illegible] of the author's (occasionally claimed by some [illegible] a pipe dream), and that, almost without exception [illegible] he has consulted about the practicability of [illegible] declared the task to be impossible of accomplish[illegible] the MS. of his book he experiences deep satis[illegible] solved the problem (and especially that portion [illegible] abutments)—at least to his own contentment. [illegible] chapter, the author desires to tender to Messrs. [illegible] Ash, his former partner and associated engineers, [illegible] in furnishing him the data for the Tulsa [illegible] bridges recorded in Table 56*a*.

CHAPTER LVII

ESTIMATES

THE making of estimates is one of the most
bridge engineer, for it is generally the first step
nection with any engineering project. Upon
correct estimate will often depend the important
projected work is to materialize; and unless he have
tion for accuracy, he will not often be entrusted with
liminary estimates for important projects.

The requisites for preparing accurate estimates

First. A wide experience in construction and in
thereof.

Second. The habit of keeping in touch, through
and otherwise, with the current prices of all materials
used on engineering works.

Third. The ability to grasp great problems, to
advance their entire development and every probable
struction, and to foresee eventualities.

Fourth. The habit of general accuracy and of
checking one's computations so as to avoid all errors of

Fifth. The faculty of systemization, so as to avoid
omission of important items of expense by the preparation
making of records.

Sixth. Absolute honesty, developed to such an extent
to materialize the project will in no way influence the mind
the estimated expense or to omit any probable item thereof.

Seventh. Good judgment to prevent a too honest intention
from overloading the estimate and thus killing the enterprise

Eighth. The courage of one's convictions, in order to be
every estimate unhesitatingly and unequivocally and
clients to have confidence in the ability of their engineer

A good fundamental rule for the preparation of any
try to round out to too great an extent each item of expense
it for contingencies, but to add a general item of contingencies
Of course, one should not record the result of the
with ridiculous accuracy, because that would shake the
in the business ability of his engineer; but it is easy
figures for each item without making it include any
This can be accomplished by diminishing as well

an average for planes and
will reduce the resultant error to very small
contingent amount to each item, he is liable to
by overloading the estimate; moreover,
added to an estimate to cover contingencies,
look askance at any estimate not containing
However, if the contingency amount be made
estimate will think that the engineer did not
that he was trying to cover his ignorance by a
cost of the unknown. What percentage should
an estimate for contingencies will depend entirely
construction and the probable difficulties to be
in the case of a viaduct over a dry gorge in a
where there are ample facilities for transportation
cuts no figure, the contingency allowance
low as two or three per cent; but in the case of
river, with foundations far below the river-
from civilization, it should be high, say from
author considers the latter figure to be the
in good engineering practice; for any larger
that the engineer had not the proper data
The experienced engineer will not
add for contingencies by either guess-work or
go through his entire list of items of cost and will
so as to decide whether it contains an
and, if so, about how much should be allowed
such allowances and perhaps adding a trifle for
order to obtain the general item.

items of expense that will aid one in figuring
project. It is as complete as the author can
would be loth to guarantee that it contains every
that may arise.. It is understood that no par-
of these items.

Expenses

including lawyers' fees, state charges,
typewriting.

the plotting of the data accumulated

work.

by the War Department.

plans and the specifications preparatory

raising the money to build the proposed

[illegible]

[illegible] piles in place [illegible]

Concrete or masonry in shafts of piers [illegible]

Coping stones for piers, pedestals, and [illegible]

Timber or stone protection for piers against [illegible]

Steel shells for piers.

Rip-rap for piers and abutments.

Mattress work for pier protection.

Earth and rock excavation.

Back filling.

Reinforcing metal for concrete.

Removal of old bridge.

Superstructure Construction

1. Superstructure metal delivered at site.
2. Floor timber delivered at site.
3. Rails and their attachments delivered at site.
4. Hand-rails delivered at site.
5. Falsework.
6. Maintenace of traffic.
7. Erection of metalwork.
8. Painting of metalwork.
9. Framing and placing of timber.
10. Laying of rails.
11. Pavement, including base therefor.
12. Operating machinery of all kinds.
13. Machinery house and shelter house.
14. Electric lighting.
15. Counter-weights.
16. Toll house.
17. Concrete.
18. Reinforcing metal for concrete.

Approaches

1. Clearing and grubbing of right of way.
2. Earthwork, including ditches and off-take [illegible]
3. Track on embankment, including ballast [illegible]
4. Frogs, crossings, switches, and signals.
5. Interlocking apparatus.
6. Culverts and tile drains.

[illegible] buildings. [illegible]

[illegible] trative officers and all other similar expenses, [illegible]

[illegible] accidents and fire.

[illegible] approximate estimates of cost should be prepared, [illegible] ing example from his practice. In May, 1907, [illegible] Edward C. Crow, formerly Attorney-General for [illegible] to give evidence in a lawsuit as to what it would [illegible] Eads and the Merchants' bridges of St. Louis [illegible] to carry modern live loads. Before giving his [illegible] a report embodying the estimates required, and [illegible] question or comment by the attorneys. The [illegible] of the said report:

[illegible]

[illegible] me to prepare for you as accurate estimates as [illegible] to replace the Eads and the Merchants' bridges with [illegible] carry modern live loads of the same general character as [illegible] structures, and using current prices of materials and [illegible] bridge, you preferred to have me figure on simple spans [illegible] of the present structure; and you desired me not to [illegible] adopt instead either steel trestle or earth embankment. [illegible] estimate on permanent construction.

[illegible] your instructions I procured a small scale plan and pro- [illegible] made a personal examination of the Eads bridge and its [illegible] ments to have made for me the next day and sent [illegible] of the approaches to the Merchants' bridge. As I [illegible] on "The St. Louis Bridge," and as years ago I was [illegible] of the competitive plans for the Merchants' bridge, [illegible] preparing the required estimates. Moreover, as

[illegible] my firm has lately made a [illegible] Bridge" at both Cass and Chouteau avenues, [illegible] latest schedule prices for the materials that would [illegible] River bridges at St. Louis.

The live loads adopted for the estimates were taken from [illegible] De Pontibus, Class R being used for the railway floor, Class [illegible] Class C for the footwalks. For the street railway floor [illegible] eighty-thousand (80,000)-pound cars on each track was [illegible] was adopted a combination of a Class U load on each railway [illegible] line, heavy vehicular traffic, and pedestrians on the other [illegible] covered by the roadways and the street car tracks (including [illegible]) and the sidewalk areas were assumed to be floored [illegible] covered with a thin layer of asphaltic concrete, on which rest [illegible] and the asphalt sidewalks. In case of doubt about the exact [illegible] been liberal in my assumption—for instance, in figuring the cost [illegible] knowing where the earth could be procured, I have allowed forty [illegible] yard, although thirty-five (35) cents would probably suffice.

The most important of the schedule rates that I have used are [illegible]

Carbon steel superstructure for river spans erected and painted, [illegible] quarters cents (4.75c) per pound.

Ditto for steel approaches, three and eight-tenths cents (3.8c) [illegible]

Railway wooden floor and rails, four dollars ($4) per lineal foot [illegible]

Creosoted block pavement for roadways, two dollars ($2) per square [illegible]

Asphalt pavement for sidewalks one dollar ($1) per square yard.

Mass of cribs and caissons of piers in place, eighteen dollars ($18) [illegible]

Concrete shafts of piers in place, twelve dollars ($12) per cubic [illegible]

Limestone facing stones in place, twenty dollars ($20) per cubic [illegible]

Granite coping stones in place, thirty dollars ($30) per cubic yard [illegible]

Excavation for pedestals, fifty cents (50c) per cubic yard.

Concrete for pedestals, eight dollars ($8) per cubic yard.

Piles in place, sixty cents (60c) per lineal foot.

Earth embankment, forty cents (40c) per cubic yard.

Railway track on embankment, including ballast, four dollars ($4) [illegible] single track.

For the cost of shore protection, right-of-way, and property damage, [illegible] any data, I had to use my judgment; but I believe I have been liberal in [illegible] ances for these items.

Please note that in estimating the cost of right-of-way I assumed values [illegible] ing to those existing at the dates when the bridges were built, and [illegible] to-day; as this appears to me to be the fairest practicable assumption.

The cost of engineering I took at the standard rate of five (5) per [illegible] cost of completed structure; and I made an equal allowance for the [illegible] interest during construction, and administration.

On the preceding basis my estimates of total cost are as follows:

EADS BRIDGE

One 550′ span at $760 per lin. ft.	[illegible]
Two 534′ spans at $745 per lin. ft.	[illegible]
Two 237′ spans at $470 per lin. ft.	[illegible]
Pier No. 1	[illegible]
Pier No. 2	[illegible]
Pier No. 3	[illegible]
Pier No. 4	[illegible]
Pier No. 5	[illegible]

Pier No. 6	51,000
Combined railway and wagon trestle, 1,350′ at $250	337,500
Highway trestle, 1,250′ at $150	187,500
Railway trestle, 1,250′ at $102	127,500
Short span, 50′ at $70	3,500
Four (4) abutments, say	60,000
Embankments, 200,000 cu. yds. at 40c	80,000
Tracks on embankments, 3,200 lin. ft. at $4	12,800
Shore protection, say	25,000
Right of way and property damages, say	100,000
Summation	$2,865,240
Engineering, financing, interest, and administration, 10%	286,524
Grand Total Cost of Structure	$3,151,764

As a check on the preceding total cost, I beg to state that Waddell and Harrington's estimate for the cost of a similar structure at Chouteau Avenue, without any allowance for financing, interest, and administration, was $3,004,000. Adding five (5) per cent for these omitted items would make the total cost about $3,150,000. This is an unusually close coincidence.

MERCHANTS' BRIDGE

Three (3) spans of 517 ft. each at $445 per lin. ft.	$690,195
Piers No. 1 & No. 4 at $65,000 each (average)	130,000
Piers No. 2 & No. 3 at $83,000 each (average)	166,000
Steel trestle, 3,160 lin. ft. at $116 per lin. ft. (average)	366,560
Five (5) short spans and their four (4) pedestals	58,000
Ten (10) abutments	138,000
Earth embankments, 640,000 cu. yds. at 40c	256,000
Track on same, 17,400 lin. ft. at $4	69,600
Shore protection, about	15,000
Right-of-way and property damages, say	50,000
Summation	$1,939,355
Engineering, financing, interest and administration, 10%	193,935
Grand Total Cost of Structure	$2,133,290

As a check on a portion of the preceding figures, I would state that the contractor's price for the three (3) main spans, four (4) main piers, and the eight hundred and fifty (850) feet of steel trestle which was built at the same time as the main spans, was a little less than one million and seventy thousand dollars ($1,070,000). This figure was tendered on the work by the unsuccessful bidder with whom I was then temporarily associated.

The corresponding figure taken from my preceding estimate of cost is one million, eighty-four thousand, seven hundred and ninety-five dollars ($1,084,795).

There is one important point in connection with my figures to which I desire to call your attention, viz., that while, because of the assumption of modern live loads, my estimates of cost of superstructure would be higher than the present values of the existing superstructures; on the other hand, my designs for substructure, while just as good in every particular, are decidedly more economic than those for the existing bridges. These two variations tend to balance each other, hence the close check in the case of the Merchants' bridge.

Very respectfully yours,
J. A. L. WADDELL,
Consulting Engineer."

While it is impossible to give accurate schedule costs of all the materials and labor in bridge construction because of their variation from time to time and on account of the different conditions at different locations, the average figures in Table 57*a*, which are based on the current American prices for 1915, may be of some assistance in making approximate estimates of cost of bridges and their approaches. These figures are not to be used for reinforced concrete bridges, because those constructions are so fundamentally different from all other kinds of bridges as to warrant their receiving a separate treatment in respect to estimating on their cost. On this account the dissertation thereon which follows later has been made somewhat elaborate in respect to detail.

The determination of the unit costs for the various portions of a reinforced concrete structure is quite a difficult matter, owing to the great variation in certain of the most important factors. Accurate values can be gotten only by estimators who are thoroughly familiar with every detail of construction work; but results sufficiently close for preliminary estimates can be secured much more easily. The most satisfactory book on this subject that the author has had occasion to employ is "Concrete Costs," by Taylor and Thompson. While that treatise is best adapted to making estimates of cost of building construction, it will be found of great value for bridges as well. It will be sufficient for an engineer's preliminary estimate to assume the concrete in place in the various portions to cost so much per cubic yard, the steel in place so much per pound, and the handrails so much per lineal foot, the values being taken as accurately as the knowledge of the estimator will permit. Other items, which are not peculiar to reinforced concrete bridges, will also have to be considered. A contractor's estimate, however, should be based upon a detailed study of all of the construction problems involved.

The principal items which enter into the cost of a cubic yard of concrete are excavation, materials, mixing and placing, and falsework and forms. The chief elements of cost for the reinforcing steel are the cost of the steel itself delivered at site and that of bending and placing. Proper allowance must also be made for overhead expenses, incidentals, and profit.

Excavation is frequently charged against the substructure concrete; but it is better practice to estimate it separately, except in the case of large river piers sunk by the pneumatic or by the open-dredging process. Where conditions warrant, excavation should be separated into different classes, as dry, wet, rock, etc., depending upon the nature of the materials to be encountered. The determination of this item of cost is not difficult, provided there is no considerable amount of rock to be removed, which is very seldom the case unless it be badly disintegrated, as it was in the foundations of a number of bridges and trestles of the author's along the Fraser River in British Columbia.

The cost of the materials for a cubic yard of concrete can be easily computed, as soon as the prices of the cement and of the aggregates and

[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible] per cu. yd.	[illegible]	[illegible]
[illegible] per cu. yd.	$15 per cu. yd.	$9 per cu. yd.
[illegible] per cu. yd.	[illegible]	[illegible]
[illegible] per lin. ft.	$1.60 per lin. ft.	$1.30 per lin. ft.
[illegible]	[illegible] per cu. yd.	[illegible] per cu. yd.
[illegible]	$25 per cu. yd.	[illegible]
[illegible] per cu. yd.	[illegible] per cu. yd.	[illegible]
[illegible] per lb.	[illegible] per lb.	5c per lb.
[illegible] per cu. yd.	$4 per cu. yd.	$3 per cu. yd.
[illegible] per sq. ft.	25c per sq. ft.	18c per sq. ft.
[illegible] per cu. yd.	$1.25 per cu. yd.	80c per cu. yd.
[illegible] per cu. yd.	$5 per cu. yd.	[illegible] per cu. yd.
[illegible] per cu. yd.	60c per cu. yd.	45c per cu. yd.
[illegible] per cu. yd.	$5 per cu. yd.	$4 per cu. yd.
[illegible] per lb.	2.6c per lb.	2.3c per lb.
[illegible] per M.	$35 per M.	$25 per M.
[illegible] per gross ton	$28 per gross ton	$28 per gross ton
[illegible] per lb.	2.0c per lb.	1.0c per lb.
[illegible] per M.	$15 per M.	$12 per M.
[illegible] per lb.	0.15c per lb.	0.10c per lb.
[illegible] per lin. ft.	20c per lin. ft.	15c per lin. ft.
[illegible] per sq. yd.	$3 per sq. yd.	$2.40 per sq. yd.
[illegible] per cu. yd.	$7 per cu. yd.	$5.50 per cu. yd.
[illegible] per sq. yd.	$1.30 per sq. yd.	$1.10 per sq. yd.
[illegible] per sq. yd.	$3 per sq. yd.	$2.50 per sq. yd.
[illegible] per M.	$25 per M.	$20 per M.
[illegible] per sq. ft.	10c per sq. ft.	8c per sq. ft.
[illegible] per sq. ft.	15c per sq. ft.	12c per sq. ft.
[illegible] per sq. ft.	25c per sq. ft.	18c per sq. ft.

serious difficulty. The cost of
the largest items in a job, and it varies so
that reasonably correct results can be reach
plete outline of the method of construction. It is
tion of cost that makes the estimating on reinfo
a difficult matter.

The cost of steel delivered at the site can be
cost of bending and placing it, however, is quite
a large factor in the total cost.

The expense for handrails is largely a matter
fluenced greatly by the elaborateness of the design.
it usually forms but a small proportion of the total

The cost of other items will not differ greatly
structures. Structural and cast metal may run
unless large amounts are used.

In what follows there will be given notes, tables,
use in preparing preliminary estimates.

Figs. 57*a* and 57*b* can be used to find the cost of
cubic yard of concrete when the costs of the cement
known. In making up these figures, the amounts of
broken stone or gravel for one cubic yard of concrete
were employed, a barrel of cement being considered to

TABLE 57*b*

AMOUNT OF MATERIALS REQUIRED FOR ONE CUBIC YA

Coarse Aggregate	Broken Stone 45% Vo	
Proportions by Parts	1:2:4	1:3:
Cement, barrels	1.51	[illegible]
Sand, cubic yards	0.45	[illegible]
Broken stone or gravel, cubic yards	0.89	[illegible]

feet. To utilize these diagrams, it is necessary to enter
cost of cement per barrel, trace horizontally to the
cost of the sand per cubic yard, then vertically to the
the cost of the broken stone or gravel per cubic yard,
tally to the side, where the cost of all the materials
concrete is read directly. The lines to be followed
$1.50 per barrel, sand 80 cents per cubic yard, and broken
$1.20 per cubic yard, are indicated on the figures. The
represent fair average values for a number of jobs
thor's firm, and can be used for preliminary estimat
are at hand. The prevailing price of cement can

however, and it will rarely be advisable to omit looking it up. To this there should be added the freight rate, and also about ten cents per barrel to cover the cost of unloading, etc. The costs of the aggregates are not so important, although they should be obtained when possible.

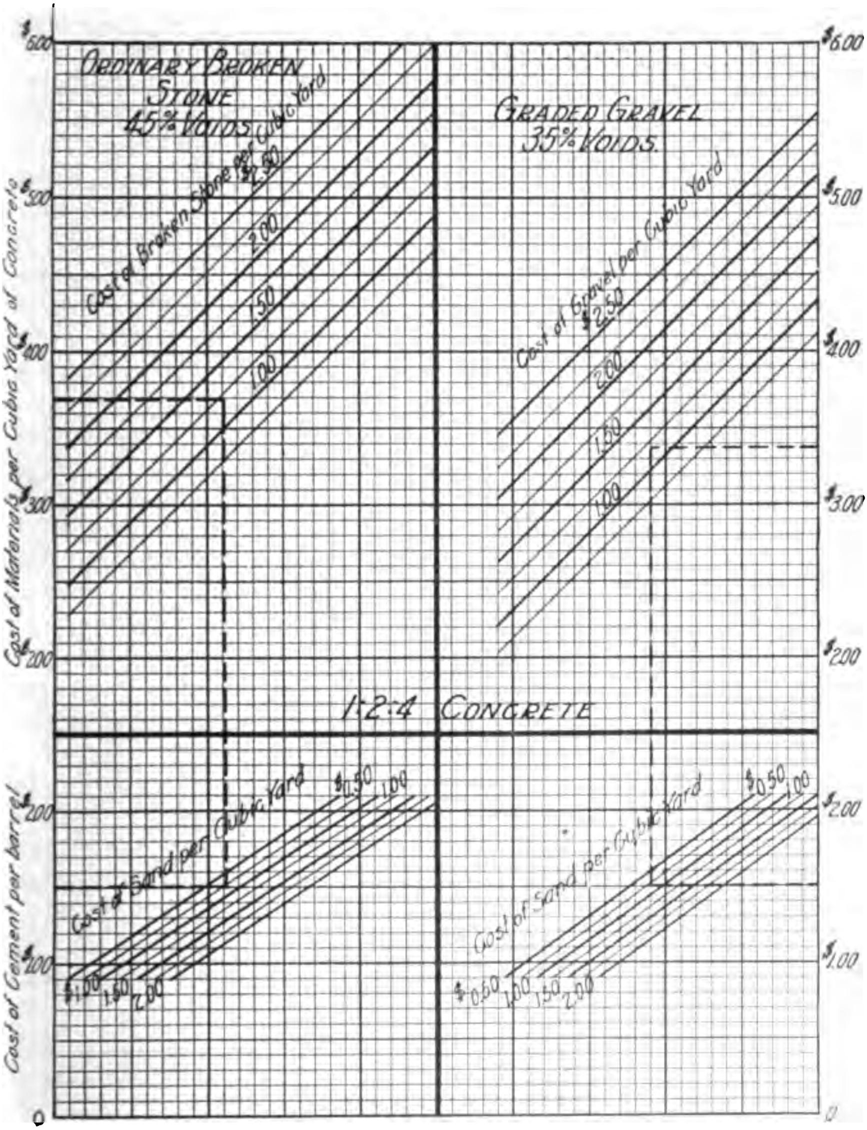


FIG. 57a. Cost of Materials in One Cubic Yard of 1:2:4 Concrete.

If materials have to be handled by wagon for some distance, the prices will have to be increased. Estimates should be made on the assumption that broken stone will be used unless it is known positively that well-graded gravel can be obtained. The curves cover the extreme ranges of

prices of materials that may be expected. Prices of cement are given in *Engineering News* the first of each month.

The cost of mixing and placing concrete will vary in extreme cases from 50 cents to $2.50 per cubic yard. On large jobs (say 10,000 cubic yards) under average circumstances it may be expected to run about $1 per cubic yard, and for somewhat smaller jobs $1.50 per cubic yard. For jobs containing less than 1,000 cubic yards the cost may go as high as $2 per cubic yard. These figures include a proper allowance for the cost

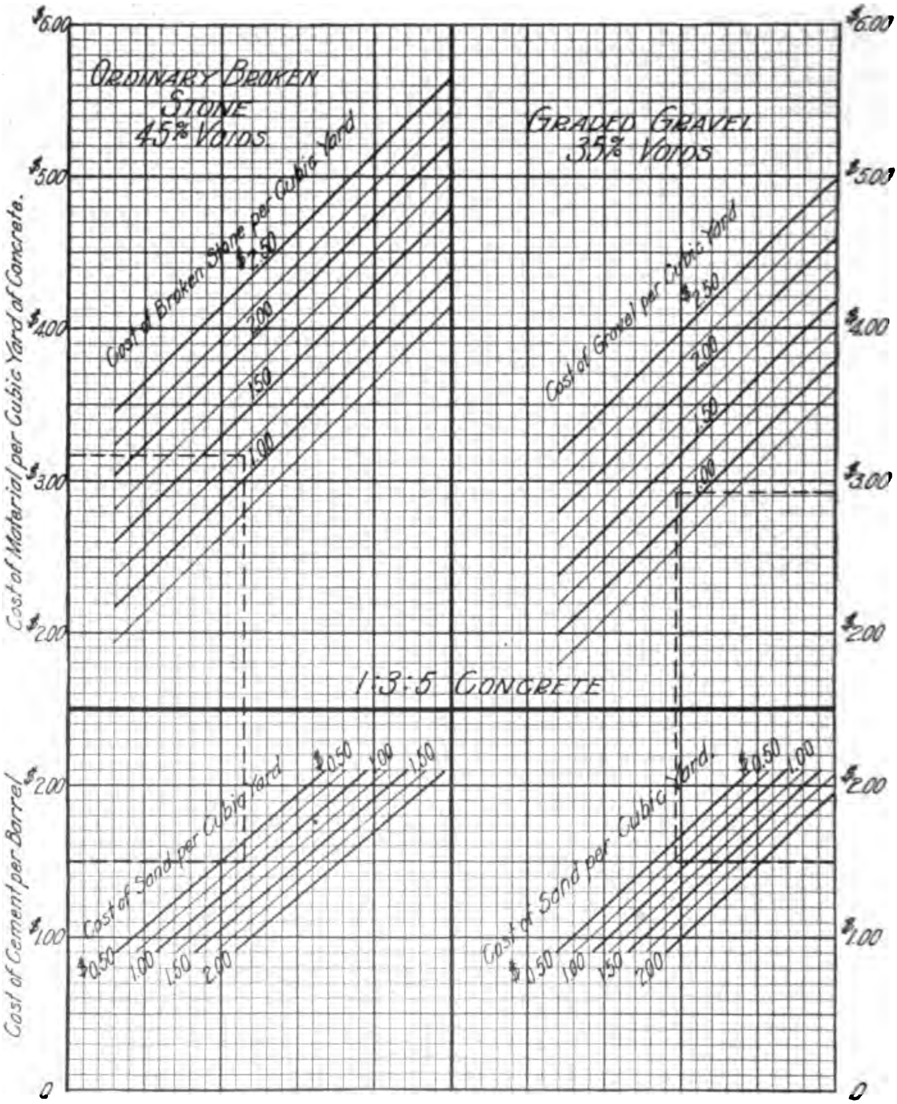


FIG. 57b. Cost of Materials in One Cubic Yard of 1:3:5 Concrete.

[illegible]

[illegible] per square foot of [illegible] given on pages [illegible] in some cases. These [illegible] responsibility insurance [illegible] delivered at site on each [illegible] base at Pittsburg plus the freight rate [illegible] obtained from *Engineering News-Record* [illegible] rates to a number of points [illegible] to inland points should [illegible] should be noted that small bars cost [illegible] fair average price for reinforcing steel delivered [illegible] ¾ inch in diameter or greater, and 2¼ cents [illegible] must be hauled by wagon for some distance.

[illegible] bending, and placing reinforcement may [illegible] per pound as an average. This figure makes [illegible] expenses, but none for profit or wastage. [illegible] excavation in the dry, including that of [illegible] cents per cu. yd. of earth. Deep or under- [illegible] $3 per cu. yd. of earth removed. Rock ex- [illegible] to $3 per cu. yd. of rock removed.

[illegible] allowance for profit, wastage, and home-office [illegible] provided adequately for all overhead expenses and [illegible] of ten (10) to twenty (20) per cent should be [illegible] both materials and labor. A fair average allow- [illegible]

[illegible] the maximum, minimum, and average prices [illegible] at site, taken from the records of the re- [illegible] which have been designed by the author's firm.

TABLE 57*c*

[illegible] Concrete Structures, Delivered at Site

[illegible]	Range	Average
[illegible]	$0.90 to 2.10	$1.50
[illegible]	0.50 to 1.50	0.80
[illegible]	0.75 to 2.00	1.20
[illegible]	0.75 to 2.00	1.20
[illegible] per pound	1.5c to 2.8c	2c
[illegible] pound	1.6c to 3.05c	2.25c
[illegible]	2.5c to 4.5c	3.5c
[illegible]	2.5c to 5.0c	3.5c

Table 57*d* presents similar information regarding the unit prices paid by his clients for materials in place in completed structures.

TABLE 57*d*

COST OF MATERIALS FOR REINFORCED CONCRETE STRUCTURES, IN PLACE

1:2:4 Concrete Used

	Range	Average
Concrete in pier and column bases, per cu. yd.	$8.00 to $11.50	$9.00
Concrete in pier and column shafts, per cu. yd.	9.00 to 12.00	11.00
Concrete in main girders, per cu. yd.	10.50 to 15.00	13.00
Concrete in cross girders and cantilever beams, per cu. yd.	10.50 to 15.00	13.00
Concrete in fascia girders, etc., per cu. yd.	11.50 to 16.00	14.00
Concrete in slabs, per cu. yd.	9.00 to 15.00	12.50
Concrete in arch rings, per cu. yd	12.00 to 17.00	13.50
Concrete in stairways, per cu. yd	15.00 to 30.00	20.00
Concrete in retaining walls, per cu. yd.	9.00 to 15.00	11.50
Handrails on bridge, per lin. ft.	2.00 to 5.00	3.00
Handrails on stairways, per lin. ft.	2.50 to 6.00	3.50
Reinforcing steel, ¾" and over, per lb.	2.5c to 4c	3c
Reinforcing steel, under ¾"	2.6c to 4.25c	3.25c
Structural steel, per lb	4c to 6c	5c
Castings, per lb.	3.5c to 7c	5c
Wrought-iron drain pipes	4c to 8c	6c

The unit prices in this latter table include all expense items of every sort. The corresponding costs of the materials delivered at site are those given in Table 57*c*. The average cost of mixing and placing concrete for these jobs was about $1.50 per cubic yard, and the average cost of materials in the concrete, by Fig. 57*a*, was about $3.70, so that the average cost of materials, mixing, and placing was about $5.20. Adding 15 per cent for profit and wastage, this item becomes $5.98, say $6. The average values given in Table 57*d* can be used ordinarily, modified for the differences in the cost of materials. Thus, if for any job cement costs $1.80 per barrel, sand $1 per cu. yd., and broken stone $1.50 per cu. yd., and the cost of mixing and placing is $2 per cu. yd., the average unit costs for concrete in place should be increased by $1.15\ (4.50 + 2.00) - \$6.00 = \$1.47$ per cu. yd. In a similar manner, if for any job the price of reinforcing steel ¾ inch or larger is 1.25 cents f.o.b. cars at Pittsburg, and the freight rate is 0.30 cents, the cost of the steel in place will be $1.15\ (1.25 + 0.30 + 0.70) = 2.59$ cents.

In preparing preliminary estimates of cost one should be liberal but not extravagant; for clients will readily forgive an inaccuracy by which they save money, but they will remember unfavorably for a long time an engineer whose estimates have been materially exceeded by the actual cost of the work. There are certain allowances for extras that should always be made; for instance, permissible excess in weight of metal, which amounts to from one to three per cent, according to the character of the construction;

[illegible] from drawing [illegible]
[illegible] ends and injury in driving. [illegible]
[illegible] be carefully checked and counter-checked
[illegible] The errors of most common occurrence
[illegible] from failure to multiply or divide certain
[illegible] in twice of some item of expense by having
[illegible] covered also in some other item. These are the
[illegible] are, unfortunately, the most difficult ones to
[illegible]metic can be corrected by anyone, but the
[illegible]gineer's estimate can be done only by another

[illegible]inary estimate of a most unsatisfactory [illegible]
[illegible] a bridge engineer has to make. It is often but
[illegible], and as such is objectionable to any high-class
[illegible] generally insists upon his making it in spite of his
[illegible] is to preliminary estimates of cost of bridges based
[illegible] profiles and the few data they may contain
[illegible] which would affect the substructure design. In
[illegible] to proceed is to take one crossing at a time,
[illegible] the best average span length for it based upon
[illegible] the insufficient substructure data (erring, prefer-
[illegible] in respect to the said length), find from weight
[illegible] weight of metal per lineal foot for the railway
[illegible] load, assume the pound price of the metal erected
[illegible]ration all the conditions that would affect it,
[illegible] foot of the superstructure, including the track
[illegible]owance for engineering and inspection, assume
[illegible] of span for the entire substructure is equal to
[illegible] (an error which is generally on the side of
[illegible]ther, allowing ten (10) per cent additional for
[illegible] uncertainties involved be greater than usual.
[illegible] about right in most cases, but occasionally it
[illegible] entire cost of the completed structure has been
[illegible] error in this connection lies in the determi-
[illegible]structure required, the tendency on the part of
[illegible] being to shorten it unduly. The consulting
[illegible] to consider the opinion of the company's en-
[illegible]sult being that further investigation of the
[illegible]ening of the structure. Again, the rock shown
[illegible]lly assumed as hard and suitable for founda-
[illegible] proves to be the case. This condition
[illegible] of structure because of the expense for
[illegible]aterial, but also increases the total length

[illegible]

[illegible] estimate of the [illegible] and the [illegible] and comparative estimates [illegible] for any projected work by [illegible] involved.

In compiling the cost of maintenance, [illegible] assume a long term of years so as to [illegible] length of time should be determined by the [illegible] important renewals or repairs; for instance, the replacing [illegible] of the renewal of timber approaches. The [illegible] of maintenance, renewals, and operation, [illegible] complete, will aid one materially in pre[illegible] [illegible]:

1. Painting of metal.
2. Renewal of timber floor or pavement.
3. Renewal of handrails.
4. Renewal of timber approaches or the replacing [illegible] earth embankments.
5. Renewal or repairing of shore protection.
6. Renewal or repairing of draw protection.
7. Repairs to operating machinery
8. Pointing of masonry.
9. Adding of rip-rap.
10. Renewal of track rails.
11. Repairs to lighting apparatus.
12. Fuel, oil, and waste for operating machinery.
13. Fuel for heating.
14. Electric or other lighting.
15. All rents.
16. Salaries of bridge tenders.
17. Salaries of track repairers.
18. Salaries of officers of the bridge company.
19. Salaries of toll collectors.
20. Salary of bookkeeper or accountant.
21. Electric power for operating opening span or for [illegible]
22. Insurance.
23. Taxes.

The estimating of revenue is often a most difficult [illegible] one hand there is the almost unavoidable desire to [illegible] possible, and on the other there is the danger of [illegible] profit or of failing properly to anticipate future [illegible] If a highway bridge is contemplated for a crossing [illegible]

[illegible]

what the annual travel per inhab
of the structure on the increase of popu
this possibility should not be given too
of the people of the vicinity will
amount of annual travel per inhabitant
if the people want the proposed bridge
information thus obtained must be taken
engineer must not forget that while the
certain to increase, the toll rates are likely to be
remember that with increased traffic come
repairs and renewals.

revenue are the carrying of the mails and express.
electric lighting, and power lines, and pipes for water,
by a bridge are a source of revenue—not great, it
considering.

time required for completion and of the amounts of
payments, as well as of the amount to allow for interest
be made with a fair degree of accuracy by an
wide experience in bridge building and in dealing
estimates of this kind due account should be taken
time of commencement of field operations, condi-
labor markets, and the amount of difficulty that
the work. A good example of an estimate of
Chapter LXX, which treats of "Reports."

also an example of comparative estimates of
structures when compound interest is considered.
the proper method of comparison is the ascer-
structure will have cost after the expiration of a
when all of the structures compared are in like
and value. Another method of comparison is to
first costs, sum these up for each case, and

table given in Table 57*e* will be found very
estimates of cost of this kind.

at 3 per cent, money will double itself in 23½
years, at 5 per cent in 14.2 years, and at 6

incidentally in the case of reinforced concrete,
been treated solely from the point of view
which should be identical with that of the

railroad engineer, but there are other bridge engineers than consulting ones, and they have estimates to make of a different kind, consequently the remainder of this chapter will be devoted mainly to their needs. The other engineers referred to are those of the bridge manufacturers and erectors; and they outnumber the consulting engineers probably ten to one.

TABLE 57e

COMPOUND INTEREST TABLE

Values of one dollar at compound interest, compounded yearly, at 3, 4, 5 and 6 per cent from 1 to 50 years.

Years	3%	4%	5%	6%
1	1.03	1.04	1.05	1.06
2	1.0609	1.0816	1.1025	1.1236
3	1.0927	1.1249	1.1576	1.1910
4	1.1255	1.1699	1.2155	1.2625
5	1.1593	1.2166	1.2763	1.3382
6	1.1941	1.2653	1.3401	1.4185
7	1.2299	1.3159	1.4071	1.5036
8	1.2668	1.3686	1.4774	1.5938
9	1.3048	1.4233	1.5513	1.6895
10	1.3439	1.4802	1.6289	1.7908
11	1.3842	1.5394	1.7103	1.8983
12	1.4258	1.6010	1.7958	2.0122
13	1.4685	1.6651	1.8856	2.1329
14	1.5126	1.7317	1.9799	2.2609
15	1.5580	1.8009	2.0789	2.3965
16	1.6047	1.8730	2.1829	2.5403
17	1.6528	1.9479	2.2920	2.6928
18	1.7024	2.0258	2.4066	2.8543
19	1.7535	2.1068	2.5269	3.0256
20	1.8061	2.1911	2.6533	3.2071
21	1.8603	2.2787	2.7859	3.3995
22	1.9161	2.3699	2.9252	3.6035
23	1.9736	2.4647	3.0715	3.8197
24	2.0328	2.5633	3.2251	4.0478
25	2.0937	2.6658	3.3864	4.2919
30	2.4272	3.2434	4.3219	5.7435
35	2.8138	3.9460	5.5166	7.6861
40	3.2620	4.8009	7.0100	10.2858
45	3.7815	5.8410	8.9850	13.7646
50	4.3338	7.1064	11.6792	18.4190

The engineer of a bridge manufacturing company is generally called upon to estimate only on the cost of metal delivered at site. In doing this he will find the following list of items of cost to be of service:

1. Materials delivered at shops.
2. Drawings.
3. Templates.
4. Laying out the work.

5. Shearing.
6. Straightening.
7. Punching.
8. Assembling.
9. Reaming.
10. Riveting.
11. Milling.
12. Annealing.
13. Boring.
14. Forging, if any.
15. Casting, if any, including patterns, foundry work, and machining.
16. Painting.
17. Loading.
18. Freight to site.
19. General expense.

The "General Expense" should include the following items:

1. Correspondence.
2. Accounting.
3. Estimating.
4. Designing.
5. Office rental.
6. Light.
7. Heat.
8. Power.
9. Repairs to machinery.
10. Renewals of machinery.
11. Insurance.
12. Taxes.
13. Rent.
14. Interest on money invested.
15. Contracting.
16. Traveling.
17. Office supplies.
18. Unassignable labor (such as yard labor).
19. Errors and defects.
20. Superintendence.

Each manufacturing company has a way of its own for figuring the general expense, consequently in dealing with this matter the author will proceed no farther, for he deems that in offering the preceding list he has penetrated far enough into the private affairs of the manufacturer of bridge metal.

The engineer of the superstructure erector in estimating the probable cost of his work will need to include the following items:

1. All other materials than metal, delivered at site.
2. Freight on equipment both ways.

3. Transportation of men both ways.
4. Unloading of materials.
5. Falsework.
6. Maintenance of traffic.
7. Removal of old structure.
8. Erecting.
9. Riveting.
10. Framing and placing of timber floor.
11. Laying of track.
12. Building of base for pavement.
13. Paving.
14. Cleaning and painting of metalwork.
15. Removal of falsework.
16. Disposal of falsework.
17. Repairs and renewals of equipment.
18. Superintendence.
19. Contingencies.

The engineer of the substructure contractor, preparatory to the bidding, will need to take cognizance of the following items in making estimates of cost:*

General Expense

1. General office expense.
2. Traveling.
3. Interest.
4. Legal expense, local taxes, permits, etc.
5. Employers' Liability insurance
6. Transportation of men, including their time while traveling.
7. Plant rental.
8. Freight on plant—both ways.
9. Unloading and installing plant.
10. Dismantling and reloading plant.
11. Maintenance and repairs of plant.
12. Tools and general supplies.
13. Temporary buildings.
14. Superintendence and local office force.
15. Local office expenses.
16. Camp expenses.
17. Fuel and water.
18. Donations and charities.

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* These data for substructure were furnished by Lee Treadwell, Esq., Member of the American Society of Civil Engineers and at the time Vice-President and Engineer of the Union Bridge & Construction Co.

of all materials for temporary

forms, shoring, etc.

Labor

materials.

hoisting out.

of the excavated material.

shores and back-filling.

delivering piles to the driver.

piles.

ready for capping.

materials from stock piles into mixer or onto mix-

[illegible]

concrete and placing it in wheelbarrows or in

[illegible]

concrete from mixer and tamping it in place.

removing forms.

pointing up work after forms are removed.

storing.

yard to derrick which sets stone.

mixing mortar.

stock piles.

securing in final position.

and crib.

mooring.

rock.

chamber.

g. Lighting.
h. Coffer dam and pumping.
i. Building upper shaft of pier.

9. Yard force, keeping up tracks, shifting plant carrying tools, water boys, and watchmen.

The method of doing the work and that of being paid will influence greatly a contractor's estimated cost of any construction. If he be allowed a free hand as to where to begin and how to carry on the different parts of the work, he will naturally figure lower than when he anticipates interference in such matters. If the pay is to be regular, in cash, and as full as is customary, he will estimate lower than when he fears irregular payments, or when he has to take securities instead of cash, or when the percentage retained till completion is excessive.

If the work to be done is for the Government, the contractor will have to add some fifteen or twenty per cent to his estimates to allow for red tape, guaranteeing of the correctness of the data submitted, slow payments, unnecessarily severe inspection, and the general demoralization of his force by disheartening hindrances. Nor is the Government the only sinner of this kind; for sometimes railroad engineers, and once in a great while a consulting engineer, will make life a burden to the contractor by unnecessarily severe and irresponsible inspection; consequently the task of the contractor's engineer in estimating the probable cost of work is by no means an easy one. Again, he cannot help being influenced by the amount of competition that is anticipated, although he should do his best to banish this thought from his mind before starting to prepare his estimate.

There is another kind of estimate that properly belongs elsewhere, viz., the monthly estimates prepared by resident engineers on construction. It will be considered in Chapter LXI, which treats of the "Engineering of Construction"; but it will be proper to make here a few remarks as to how the resident engineer should be governed in arranging for partial payments to the contractor as the work progresses, for this matter is often left entirely in his hands. In figuring the value of the work done and the materials furnished, the exact net cost to the contractor should not be adopted, but a fair allowance should be made for his general expenses and his profit; because before he is paid there is always a reduction of ten or fifteen per cent made from the amounts of the monthly estimates, which difference is retained until the completion of the entire work. If a good and sufficient bond for the proper completion of the contract has been provided, as it always should be, there is no risk in allowing the contractor fairly full payments on account as the work proceeds. Liberal treatment of this kind will keep all concerned in good humor and will lubricate the wheels of progress.

In conclusion the author offers this suggestion to all engineers in

construction: "Take every precaution to
figures, compute as accurately as possible the
without adding to it for contingencies, figure in
allowance for contingencies, sum carefully all the
and counter-check your figures in every way that
stand by the resulting estimate with courage and

CHAPTER LVIII

OFFICE PRACTICE

NEARLY two decades ago, when preparing the manuscript of the last chapter of *De Pontibus*, the author wrote thus:

> "As there has been almost nothing yet written concerning the way in which work is handled in a consulting engineer's office, the author has concluded to close this little treatise with a chapter on 'Office Practice'; and as no two engineers pursue exactly the same methods, and as the author is naturally more familiar with his own than with those of others, he will deal herein solely with the established practice of his own office, which practice is the outcome of over ten years of special effort to secure the best possible results both expeditiously and economically."

The chapter referred to covered the author's personal experience as a bridge specialist up to 1897; but between that date and July, 1915, he has been the senior partner of two consulting bridge engineering firms; and the amount of professional work done has increased greatly, with the consequence that the methods of handling office affairs have had to be modified materially. In the old days it was the author's policy to be on terms of intimacy with all of his employees and to direct personally each one's work, looking himself to every important detail so as to ensure the correctness of everything going out of the office. But after the establishment of the first of the two firms referred to, the amount of business undertaken reached such dimensions that a division of responsibility became necessary; and gradually the handling of the drafting office was entrusted to others so as to leave the author free to attend to the business of the firm, the traveling, the general studies of crossings and layouts, the preparation of specifications, the general supervision of the progress of construction, and the making of periodical visits to the fieldwork. As time passed and as the amount of work undertaken continued to increase, it became necessary for him to share some of these duties also with his partner and the firm's principal assistant engineers; and the redivision of duties and personal responsibilities continued steadily until of late years the author's attention has been devoted mainly to the higher portions of the work, including the dealing with governments both at home and abroad, the making of important technical investigations of a general nature, the preparation of forms and instructions for writing specifications and contracts and for doing other work in both office and field, and attending to a share of the necessary traveling. On this account many of the changes in details of the office practice have been evolved by his partner and the firm's employees; and they are recorded in the discussion which follows:

[illegible] only those who are personally [illegible] efficiency; and, consequently [illegible] any material. [illegible]

[illegible] CALCULATIONS AND DRAWINGS [illegible]

Laying Out Work. [illegible] entirely to office-work, it will be assumed [illegible] field data as profiles, maps, plats of borings [illegible] necessary to determine the following:

[illegible] which *the Structure is to be Used.*—This being [illegible] of the live load, the spacing of trusses [illegible] height above base of rail or surface of roadway.

[illegible] between *Standard High Water and the Lowest* [illegible] If the stream be a navigable one, the minimum [illegible] by the requirements of the War Department, as [illegible] L. In other cases the clear height will depend [illegible] of grade of railroad or roadway, provided that [illegible] structure will never offer any obstruction to [illegible] the highest floods. The minimum clearance [illegible], and never less than five. Where a low bridge [illegible] stream, the best type to employ is to be de[illegible] Chapter XXVIII; and the type selected is to be [illegible] the information given therein and in one of [illegible] preceding chapters. Restrictions concerning both [illegible] clearances for railroads and traffic-ways crossed [illegible]

[illegible] *to Adopt.*—In many cases there will be no [illegible] which are liable to be determined by such condi[illegible] of the War Department, obstruction of stream [illegible] during erection, etc.; but, where the designer [illegible], he should be governed by the principles of [illegible] LIII, taking care, however, that he does [illegible] of æsthetics given in Chapter LII, unless [illegible] circumstances that are absolutely beyond his [illegible] LIII, in steel bridges the greatest possible [illegible] cost of each pier is equal to one-half of the [illegible] systems of the two spans which it helps to

support. The determination of these economic conditions is, of course, a matter of cut-and-try; but after a few trials the economic span length can be approximated very closely. In making such calculations the trial weights of trusses and laterals can be found from Chapter LV. The economic span lengths for reinforced concrete bridges, which are generally more difficult to determine than those in steel structures, are discussed in Chapter LIII; and diagrams giving quantities are to be found in Chapter LVI. In reinforced-concrete arch bridges the span lengths, when not determined by physical conditions, should be settled by general economic principles, including the balancing of thrusts so as to reduce to a minimum the eccentricities of loading on the foundations.

The method of determining the layout is discussed very fully in Chapter LIV; and the determination of the waterway, in Chapter XLIX.

Fourth. General Layout of Structure.—The general layout should consist of a profile, a plan, and enough cross-sections to illustrate properly the entire substructure, superstructure, and approaches, all being made to exact scale. For long crossings, a scale of one-fortieth of an inch to the foot is the most satisfactory, but for short crossings the scale should be made larger. The proportioning of the skeleton of the trusses should be done in accordance with the suggestions given in several of the preceding chapters, and the dimensions of the piers should be determined by the principles established in Chapter XLIII.

Each general layout should give the following information:

Borings, low water, standard high water, extreme high water, lowest part of structure, grade-lines, and tops of piers; lengths of all spans between centres of end-pins or centres of bearings; distances between centres of piers; clear openings for movable spans; vertical clearance above extreme high water for lift spans; and lengths and kinds of approaches.

As soon as the general layout is completed and finally adopted, the computations of stresses and sizes of members of spans may be begun.

For elevated railroads it is necessary to determine the following:

A. The number of tracks on the various portions of the line, and the clearances over streets and alleys.

B. The live load per track to be carried by the structure.

C. The location of the line, whether in the streets or on private property.

D. The style or styles of girder construction. In some locations the city ordinances may require open-webbed girders, as these shut out less light than do solid-plate girders, while in other locations the plate girders would be permissible.

E. The location of columns, whether in the street or on the curbs, also, for location on private property, the number of columns per bent.

F. The economic span length. As indicated in Chapter LIII, the greatest economy will exist when the cost of the longitudinal girders is

equal to the cost of the cross-girders, columns, and pedestals. Where the columns are located in the street or on the curbs, due consideration must be given to the probable cost of removing underground obstructions, such as water-pipes, gas-mains, etc.

G. Where a structure is on a sharp curve it is sometimes advisable to make the bents radial; but, whenever practicable, it is best to make the towers perfectly rectangular and to throw the skew entirely into the intermediate span, so as to simplify and cheapen the shopwork. The exact location of each column should be figured from certain known lines, and all ordinates for the same should be indicated on the layout.

Much careful study should be given to the work of establishing each feature of the layout; for, if mistakes be made therein, they are likely to cause great delay and expense later on. With these points all settled, the calculations for proportioning all parts of the structure may be proceeded with.

Calculations

After the leading features of any proposed structure have been settled, and after the general layout thereof is completed, the next step to take is the making of the calculations necessary to determine the stresses in all the parts and the proper sizes for same. For convenience in making to correct scale pen-sketches of the various portions of the design, the author uses a cross-section paper divided into one-quarter-inch squares, the sheets being ten and a half inches wide by sixteen inches long, which size experience has shown to be the most satisfactory. At the head of each page are written the date, title of structure, and name of computer. This form is shown in Fig. 58*a*.

Each set of calculations is started by filling out all the blanks on a data-sheet of the same size as the calculation sheets, but not ruled into squares. This data-sheet is illustrated in Fig. 58*b*.

Before figuring each truss span there should be recorded for it the following:

First. Length..

Second. Number of panels.

Third. The various truss depths.

Fourth. Perpendicular distance between central planes of trusses.

Fifth. Spacing of stringers.

The dead load from the track and ties in railroad bridges, or from the timber floor or pavement in highway bridges, is first determined, using the unit weights of materials given in Chapter V; then the stringers or longitudinal girders are figured and proportioned, after which their weights and that of their bracing are computed.

Next the floor-beams or cross-girders are proportioned, and their weights are figured. From all these weights the weight per lineal foot of the metal in the floor system is next found.

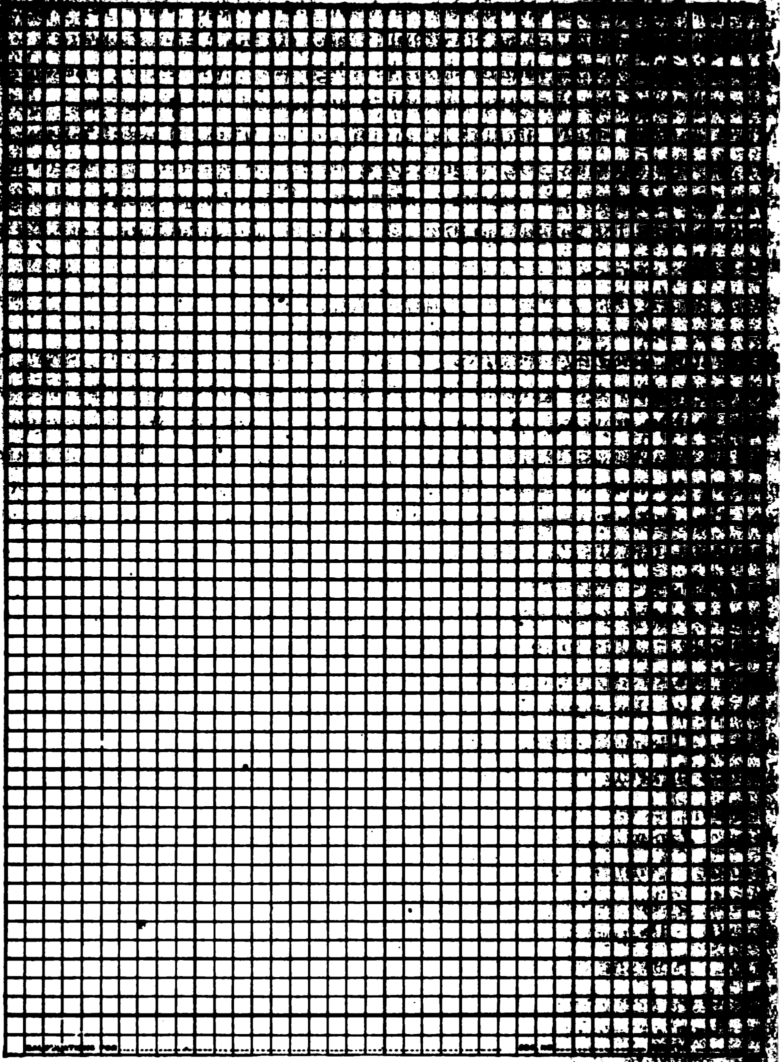


Fig. 58*a*. Calculation Sheet.

[illegible] AND GAUGES OF TRACKS AND CHARACTER OF LIVE LOAD

[illegible] BY TRUSSES

[illegible] OF RAIL

VERTICAL

DISTANCE C. TO C. TRUSSES

ELEV HIGH WATER

ELEV LOW WATER

REQD CLEAR DISTANCE BETWEEN END PIERS AT RIGHT ANGLES TO STREAM

[illegible] ANGLES TO DIRECTION OF CURRENT

TIME REQD TO OPEN OR RAISE SPAN

CLOSE OR LOWER SPAN

Data Sheet for Calculations.

As the lateral system can nearly always be designed before the trusses, it is generally best to compute the weight per lineal foot of the entire lateral system before the trusses are touched, because the dead load for the latter will be affected by the weight of the former.

Next it is necessary to assume the weight of metal per lineal foot for the trusses. This completes the data for the preliminary dead load, which will consist of the following items:

First. Flooring (timber, track, pavement, etc.).

Second. Floor system (stringers, stringer-bracing, and floor-beams).

Third. Lateral system (upper and lower lateral systems, vertical sway-bracing, and portal-bracing).

Fourth. Trusses.

In making up the dead load, the end floor-beams and pedestals must not be included, as their weight produces no bending moment on the span.

The dead-load stresses in trusses are always found analytically for spans with parallel chords and equal panel-lengths; but for other cases they are usually determined graphically, and are checked by a single numerical calculation at the member where the graphics stop, as explained in Chapter X. They are recorded on a skeleton diagram of the truss.

The live-load stresses are found by the method explained in Chapter X, and are recorded on a separate skeleton truss diagram. Whenever it is practicable, in making arithmetical computations, the slide-rule is employed. For ordinary work, in which the total stresses can be written with six figures, a ten-inch slide-rule will give the stresses accurately in thousands of pounds; but where the stresses are greater, Thacher's cylindrical slide-rule can be employed, although the ten-inch slide-rule is generally sufficiently accurate.

The computation of all stresses found analytically is facilitated by determining the trigonometrical functions involved in the calculations, and multiplying the panel loads by them. By setting these products on the slide-rule and using the proper tabulated coefficients—given in Tables 10*b* to 10*i* inclusive—it is often practicable to read off a large series of stresses without resetting the slide.

The impact stresses are found from the live-load stresses by slide-rule, using the diagrams given in Figs. 7*c*, 7*d*, and 7*e*, and are written, preferably, upon a separate skeleton truss diagram; although some computers prefer to record them on the live-load skeleton diagram, each impact stress being placed directly beneath the live-load stress to which it corresponds.

Next are computed all the wind-stresses which could possibly affect the sizes of the sections of main-truss members, and these are recorded either on a separate diagram or on one of those already prepared, in the latter case care being taken to indicate that each such stress is marked as a wind-load stress.

Next the various combinations of all stresses are made and recorded

on a new diagram, after which the required sectional areas of all main members are figured according to the specifications, and are written on the same diagram; then the actual sections are proportioned and recorded there also.

In order to prevent waste of time by carrying calculations to an unnecessary degree of refinement, and so as to conform to established conceptions of fitness and proportion, the instructions given in Table 58*a* have been prepared for the use of the author's assistant engineers.

TABLE 58*a*

Accuracy of Calculations

In all calculations figures are to be given to the nearest unit noted in the following table:

1. Effective span	0.1 ft.
2. Effective depth	0.05 ft. or 0.5 in.
3. Height to lift	1.0 ft.
4. Loads	
a. Per square foot	1 lb.
b. Per lineal foot	10 lbs.
c. Concentrated	100 lbs.
d. Load to lift	1000 lbs.
5. Shears	1000 lbs.
6. Stresses	1000 lbs.
7. Moments.	
a. Stringers, floor-beams, etc.	100 ft. lbs. or 1000 in. lbs.
b. Main girders	1000 ft. lbs.
8. Live-load impact	0.5%
9. Ratio $l \div r$	1 unit
10. Unit stresses	10 lbs.

Next the weight of metal in the trusses is estimated. For ordinary spans, the weights of details are taken from Figs. 55*f* and 55*w*; but if the structure be of an unusual type or size, the details are sketched and their weights are computed.

Next the total weight of metal in the structure is figured, and the dead load is checked. If it does not agree with that assumed within the limit of error set in the specifications, a new dead load is assumed, and the entire computations of total stresses, sections, and truss weights are made anew. It is very seldom, however, that it is necessary to make these calculations more than once, owing to the great mass of accumulated data concerning weights of metal in all kinds of bridges, as recorded in Chapter LV.

The exact lengths of all members, including camber allowances, are then figured and recorded on the last-mentioned diagram, preferably in blue ink.

In determining stresses graphically, the frame diagram should be laid out on as large a scale as is convenient, and the load diagram should be made as small as practicable; for the large frame gives great accuracy in inclinations of members, which is the all-important point in graphical computations, and the small load-diagram confines the graphics to a reasonable space. If the inclinations are correct, accurate results will be

[illegible] work has to be done over. [illegible]
[illegible] perfect, straight-edges, [illegible]
[illegible] which list should be added [illegible]
[illegible] of the appliances.

The calculations for girder spans and for [illegible]
are made in a similar manner to that just
cept that in trestles and viaducts attention has to
binations of stresses in towers, as explained in Chapters

In respect to the calculations for reinforced
ject has been very thoroughly treated in Chapter
nothing further on the subject need be said here.

In regard to the calculations for reinforced
trestles, the sequence of designing is as follows:
cross-girders, main girders, columns or piers, and
of figuring each of these items is very thoroughly
XXXVII, hence there is no necessity for making here
thereon.

Checking Calculations

In making any set of calculations the computer
his work at short intervals, so as to see that no
because the effects of such errors often extend over
putations.

All calculations on the standard sheets, except
cated, are made in black ink; and when they are
computer, as is the invariable custom in the author's
marks and corrections are made in red ink, and each
marked and initialed by the checking computer, who
all the numerical calculations, but also follows carefully
design so as to guard against all possible errors. The
is greatly facilitated if all the steps taken are indicated
they can be easily followed by the checker. Each result
off with red ink.

Making Drawings

Owing to the necessity for having several copies
ing, the latter is first laid out in pencil on detail
ink on tracing cloth. In some simple designs, however,
done directly on the tracing-cloth, but this is the
the rule. For convenience in handling and filing,
have all drawings made of a uniform size. After

ence, a size of twenty-nine inches in width and thirty-eight inches in length has been adopted as best suited for bridge plans. This size may be used for all detail drawings and stress-diagrams, but it is often necessary to increase the length for profiles and general drawings. The drawing is always made on the rough side of the tracing-cloth, as it is often convenient to do a considerable amount of drawing and writing in pencil on the sheet. Another reason for using the rough side is that any erasure shows less thereon than it would on the smooth side, and it is often necessary to do considerable erasing on tracings. As before stated, the first drawings to be made are the general profile and plan, with cross-sections, in order to establish all the main dimensions of the structure. These drawings can be prepared before the computations are finished. Next come the stress-diagrams, which should contain for steel structures the cambered lengths of all members; the dead load, live load, impact, and wind-load stresses, and the greatest combinations of same; the sections required and those used for each main member; and the following general data:

1. Length of span from centre to centre of end-pins.
2. Number and length of panels.
3. Perpendicular distance between central planes of trusses.
4. Depths of trusses.
5. Dead load for floor system per lineal foot of span
6. Dead load for trusses per lineal foot of span.
7. Live load for stringers per lineal foot of span.
8. Live load for floor-beams per lineal foot of span.
9. Live load for trusses per lineal foot of span.
10. Wind load on upper lateral system per lineal foot of span.
11. Wind load on lower lateral system per lineal foot of span.
12. Clearance required above base of rail or floor.
13. Specifications.
14. Kinds of materials to be employed in all parts of structure.
15. Diameters of rivets to be used.

The stress-diagram proper may be simply a line-drawing, each main member being represented by a single right line, or all the main members may be drawn to scale by means of their periphery-lines. The latter method is generally adopted because of the improved appearance of the sheet which it affords. The scale for any stress-diagram should be large enough to give plenty of room between panel points to contain all the necessary writing.

After the stress-diagrams are completed, the detail drawings are begun. There is considerable difference in the methods employed by consulting engineers to convey to manufacturers an understanding of the design which they desire to have executed in the shops. Some insist that the only proper method for the engineer to pursue, if he desires his details

[illegible] to the [illegible] general detail drawings, which [illegible] and give all important dimensions [illegible] connection, but which do not locate each [illegible] the working drawings to be made by the [illegible] method is adopted, the working drawings must be [illegible] engineer for his approval before any of the work is [illegible] and drawings being checked by the engineer's [illegible] that they agree in every important particular with [illegible] but also to make sure that they contain no errors of [illegible] method is the one which the author [illegible] adopting it he gives the following reasons:

First. Each bridge-shop has certain methods of [illegible] demand that the working drawings be made in [illegible] otherwise the cost of the manufacture is materially [illegible] methods cannot be considered by the engineer, who [illegible] nor the inclination to go to the trouble of acquainting [illegible] various methods of all the leading bridge-shops of [illegible]

Second. The nature of the work of a consulting [illegible] as to justify him in keeping together enough trained [illegible] with sufficient rapidity the large amount of drawing [illegible] first-named method be followed.

Third. The capacity for accomplishing work in a [illegible] office when the second method is employed is [illegible] great as it would be were the first method adopted.

Fourth. With the careful and thorough system of [illegible] drawings in vogue in the author's office, all the [illegible] by making complete working drawings are obtained by [illegible] method of making complete detail drawings.

Fifth. The manufacturer always appears to be [illegible] satisfied if the making of the shop-drawings be left to [illegible] of manufacturing the metal proceeds more smoothly [illegible]

In starting a detail drawing, the first thing to be [illegible] a sheet of standard size. If the subject be a [illegible] a bridge or roof truss, it will greatly economize space [illegible] the skeleton frame be laid out on a small scale, say [illegible] half inch to the foot, thus giving the proper [illegible] and if the details at all the panel points and [illegible] larger scale, say three-quarters of an inch or an [illegible] centre-of-gravity lines of all main members [illegible] lines of the skeleton diagram. For the details [illegible] scales just mentioned will be found the most [illegible] common error among bridge-draftsmen, when [illegible] used, to make the principal lines of the main [illegible]

[illegible]
often the [illegible] of [illegible]
the main members should be [illegible]
midway between the panel points, and
section of the member between the [illegible]
[illegible]
scale, the next step is to determine what
to be shown on each sheet, if more than one
the best possible arrangement for all details
uniformly and allow ample space for [illegible]
requisite number of views. For short spans
by carefully arranging the details, every
on a standard sheet of twenty-nine inches by
of all connecting-plates, stay-plates, lattice-
fillers, rivets, etc., should be given, also
and the exact spacing from back to back of
forming the various members should be
at all panel points should be shown, and
should be given by figures. There should
dimensions, such as the exact cambered
line of pin-holes for all truss-members; the
of bottom-chord pins to base of rail; the
of bottom-chord pins to bottom of floor-
from base of rail to top of masonry; the
base of rail; the spacing of anchor-bolts; the
beyond centres of pin-holes; the spacing of
floor-beams, and chord members in a general
each," or "about 3″ spacing"; the distance
flange angles in all girders and struts; the
girders; the spacing of stiffening angles; etc.,
which are to be planed or faced should be so

a general and descriptive title printed in a
The title and the number of the draw-
lower right-hand corner. This work can
and employing a hand-press. A single line
edge of the sheet should define its mar-
drawn for each boundary of the tracing,
to these boundary-lines, the blue-printer
to which to cut his prints. All lettering
a neat and workmanlike manner. Noth-
of a drawing than neat lettering. Special
dimension-lines so there can be no doubt
to fix. All notes should be written
noticed, and so that they will not

interfere with the lines of the drawing. A set of general notes should be given on each sheet of details, specifying the kinds of material, the sizes of rivets, the diameters of rivet-holes before and after reaming, the manner in which all plates are to be finished, etc. After each sheet is penciled, it should be checked carefully to see that there are no errors thereon; then, after the tracing is finished, it must be checked in detail—if possible by some one who was not concerned in its preparation. The checking, as a rule, must not be done on the tracing but on a blue print made therefrom. This prevents the tracing from being injured by handling, marking, and erasing. It also enables the checker to tell more certainly when all corrections have been made, and gives a permanent record of all changes. These prints should be plainly stamped or marked "Checking Prints." They can be destroyed as soon as it is thought advisable to do so.

As indicated at the outset, the preceding notes apply essentially to steel bridges and trestles; but in general they will serve also in relation to reinforced concrete structures. All dimensions of the concrete must be clearly shown, and the sizes and arrangement of all reinforcing bars must be properly indicated. It will frequently be advisable to make one drawing showing concrete details only, and another one for the reinforcement. A scale of one-quarter or three-eighths of an inch to the foot will usually be found satisfactory; but for complicated details, such as those at expansion joints, it will often be best to adopt a larger scale. The general notes on each sheet should cover such points as the permissible edge distance and spacing of bars, the amount of lap required at splices, the minimum radius of bend allowed for bars under stress, and the dimensions of hooks on the ends of bars. The locations of construction joints should be indicated on the drawing, or else should be covered by the general notes.

Checking Drawings

The following standard instructions of the author to his office-assistants concerning the checking of drawings will indicate what such checking should accomplish and the essential thoroughness thereof.

General Detail Drawings

First. Go over all drawings for the entire design and see that every detail of the structure is shown in a sufficient number of views to make clear to the manufacturers exactly what is intended by the designer.

Second. See that every detail has been dimensioned so that it can be readily laid out on the working drawings. See also that all sections of connection angles, fillers, etc., are indicated.

Third. See that proper descriptive notes are given wherever necessary to make clear the reasons for any special details.

[illegible] figured for each. Make sure that [illegible]

[illegible] provided for at the bottom of a [illegible] but the algebraic sum of the [illegible] for all diagonals attaching to the [illegible] and on the side of safety, the stress [illegible] panel floor-load. See that no bar diverges [illegible] more than one-eighth (1/8) of an inch to [illegible]

[illegible] are shown and their sizes given wherever they [illegible] members to exact position on the pins. Check [illegible] bending moments coming on them, determining [illegible] bending moments in two directions at right [illegible] to

[illegible] centre-of-gravity lines of all members are shown; [illegible] not in the central plane of member, see that [illegible] of the section.

[illegible] drawing is either wholly or partially shown in [illegible] point at which the section is taken is indicated [illegible] section line is properly indicated on the other views

[illegible] sections of members and all leading dimensions [illegible] calculations, and see that they correspond thereto.

[illegible] stay-plates and lacing-bars are shown, and that the [illegible] also that these sizes comply with the requirements [illegible] the inclinations of all lacing-bars should be given.

[illegible] extension-plates of forked ends are carried at [illegible] stay-plates, and that they are strong enough [illegible] of the main member, even though the com-[illegible]ally.

[illegible] forked ends for transverse bending, and see that [illegible] wherever necessary.

[illegible] reinforcing-plates at ends of members are so [illegible] nearly as practicable the bearing on the two [illegible]

Thirteenth. Compare drawings which show the same details, so as to make sure that all are alike.

Fourteenth. See that the same style of detailing has been followed on all drawings. Where several draftsmen are employed on the same piece of work, there is liable to be quite a diversity of details, illustrating the individualities of the various draftsmen making them.

Fifteenth. When a change is made in any part of a drawing, see that the said change is carried through all the sheets which are affected thereby.

Sixteenth. See that when any drawing or portion thereof is abandoned it is so indicated clearly throughout all the drawings.

Seventeenth. Wherever timber-bolts are to be used, see that they are plainly indicated, that their sizes and lengths are given, and that washers are provided beneath all heads where the bearing is on the wood.

Eighteenth. See that all screw-ends of rods are upset, unless they are to have cold-pressed threads. See that all diagonal rods are provided with proper adjustments, and that all clevis-pins and plates are of proper strength. See that no pins of less diameter than allowed in the specifications are used, and that they are set at least one and one-half diameters from edge of plate.

Nineteenth. In reinforced concrete structures, see that all dimensions of the concrete are clearly shown, that the number and the arrangement of all reinforcing bars are properly indicated, that the locations of construction joints are specified, and that at no point have unduly thin sections been used.

Twentieth. See that each sheet is provided with general notes as follows:

Steel Structures.

A. Kinds of material to be used throughout the structure.
B. Diameters for rivets.
C. Sizes of rivet-holes before and after reaming.
D. Manner in which the edges of all web-plates are to be finished.
E. What ends are to be faced and what are not.

Reinforced Concrete Structures.

F. Permissible edge distances and spacing of bars.
G. Amount of lap of bars at splices.
H. Minimum radius of bend allowed for bars subject to stress.
I. Dimensions of hooks on ends of bars.

Twenty-first. See that all notes are written in good English, that all words are spelled correctly, and that they express exactly what is intended.

Twenty-second. See that each drawing is provided with proper titles, that it is numbered correctly, that the scale or scales are indicated, and that the name of the draftsman and date of completion of drawing are given.

Twenty-third. See that the drawings scale, and, if they do not, make

written on the drawings are to be in-
where there is any discrepancy between

check over all details, dimensions, sections,
drawings, so as to make sure that everything is
the specifications and with the data furnished

that the sections and details conform in every par-
on the general detail drawings and stress-diagrams,
where slight changes may be made to facilitate
provided, of course, that such alterations do not
strength, durability, or appearance.
all field connections to see that there are no
that they cannot be satisfactorily driven in

members have proper clearances at panel-points,
wherever necessary to provide such clearances,

all lengths of members and rivet-spacing for field
that the holes will match in the field.
all bills of material to see that the correct numbers
ordered, and that they are of proper sections and

the shop-drawings sent to the office in duplicate
sets, retaining one set in the office and returning
or approval marked thereon. Where draw-
with corrections marked on them, revised prints
before the work is put into the shops.

Changes on Tracings

to make changes on a tracing, and in doing so
otherwise a drawing which has cost con-
may be ruined. For making slight erasures
best, and next comes the rubber ink-eraser,
knife skilfully used will be found effective,
as to affect nothing but the parts to be erased.
only with extreme care. Where only a
an erasing shield—a thin sheet of metal in
corresponding to the work to be changed—should
on the drawing so that a hole comes over the
eraser is rubbed over the hole, and nothing is
which is changed.

FILING DRAWINGS, CALCULATIONS, SPECIFICATIONS, ETC.

In the course of a few years' practice the office records of a consulting engineer grow to such proportions that, unless some systematic method of filing and indexing them be adopted, it is impossible to refer thereto without a great deal of delay and annoyance. The filing of calculations and specifications is a comparatively easy matter, but to keep an accumulating lot of drawings in good shape for ready reference is by no means such. During the time that the author has been engaged in active practice several methods have been employed for filing tracings. One great difficulty with the earlier drawings was that they were of varying dimensions, some as large as forty-two inches by ninety-six inches, and others belonging to the same set as small as eighteen inches square. At first large cases of drawers were used for laying out the tracings flat, each tracing being stamped with numbers designating the lot and drawer to which it belonged, and an index being kept of all drawings, recording the numbers of the lot and drawer. The objections to this method were that the smaller drawings got lost among the larger ones, thus often necessitating a complete overhauling of an entire drawer to find a tracing, and it was impossible to keep the large drawings from becoming folded and cracked at the edges and corners. Later it was deemed advisable to bind each set of drawings together with patent fasteners along one end, but this method was soon abandoned, owing to the difficulty encountered in getting out tracings for blue-printing and reference.

The method of laying the tracings flat in drawers was abandoned for a while, and that of filing them in cardboard tubes with tightly fitting covers was tried. This served the purpose fairly well, but it had its defects, hence it, in turn, was abandoned for the one now in use, which is as follows:

The tracings are filed in flat drawers in heavy paper envelopes containing about ten tracings each, there being some ten or twelve envelopes to a drawer. There is a special file for record drawings, and there is another for finally approved shop-drawings. There is also a file for calculations; and all periodicals that are not bound permanently, all important catalogues, all specifications, and all other materials that may prove of use in the future are filed methodically. All files are thoroughly indexed so that anything wanted can be found very quickly.

The specifications and calculations are kept in filing cases prepared especially for them. These cases consist of a series of small shelves about one and a half inches apart, each shelf being numbered. When a set of calculations is complete, the sheets are all bound together in one book with removable fastenings, so that they can be easily separated when it is necessary to distribute them among several draftsmen. These sets are all numbered with the numbers of the shelves on which they are to be filed.

be of an extra-good quality, as
great deal of erasing and scratching
for details. The tracing-cloth
it is impracticable to make a good drawing
that the author has ever used is the
be rubbed over the surface of the
the ink uniformly. Pencil-marks and dirt can be
tracing by moistening a towel in benzine
the cloth with it. If a good quality of ink be
by such washing.

India inks in the market, but none of them
as will the genuine stick ink when properly
except for very fine work, the former are prefer-
saving of time which they effect. Higgins's water-
factory which has yet been tried in the author's

paper is very essential, for there is in all
deal of erasing to be done; and time is always
tough paper that does not rough up by having an

Handling Office Work

given a complete description of the manner of
as developed by the author's firm; and while
the evolution of a practice extending over nearly
the drafting department is concerned it is mainly
Fox, Esq., C. E., who for many years and until
was Chief Draftsman for the firm, and who since
the author in the accumulation of data for this
this description, however, it must be remembered
have been evolved for an exceedingly large prac-
necessarily apply to an office where such a prac-
modification of the system may be advisable for
possibly it may not be applicable at all for any
consulting bridge engineer.

was carried on in what might properly be termed
consisting of the General Office or Business
Department, and the Drafting Department.
distinct in so far as each occupied quarters de-
particular work and was in charge of a single

head responsible only to the Office Manager, there was a common interest in the office as a whole which necessitated a close relationship between the various branches in order to carry on the work systematically and economically. The members of the firm had their own private offices; and while in the office they were in daily touch with all of the departments giving directions and suggestions where needed.

The General Office was in charge of a secretary or chief-clerk, under whom worked a bookkeeper, a stenographer, and an office boy. All correspondence, drawings, prints, and data of every description passed through this department, whether they were coming into or going out of the office. The secretary opened all correspondence and referred it to the persons concerned. All letters containing information regarding the work in the Designing or Drafting Departments were copied; and the copies were sent to the heads of these, as originals were not permitted to be taken out of the General Office, except in very urgent cases when it was not considered advisable to wait for the copy to be made. These copies were stamped, "For Attention of Mr. ———" or "For Information of Mr. ———." In the former case the recipient of the copy was expected to follow up the correspondence and answer it; whereas, in the latter case, he was expected to use the information given and file the copy for reference, nothing further than this being necessary.

The originals were always stamped the same as the copies; and all letters were stamped with the date and hour when received and when copied. If the copies were not sent out immediately, the recipient usually noted the fact thereon, adding the date and hour when they reached his hands. The original of all letters of interest to either member of the firm were referred to him directly. Where the "attention" note appeared, he either asked the recipient of the copy to refer the matter to him before framing the answer (if he was particularly interested in it), or laid the letter aside until the answer was placed on his desk. All letters by the heads of the departments generally passed through the hands of the Office Manager and were sent by him to the General Office for mailing. All original letters received were filed by the General Office, the copies being kept in the files of the department heads. Copies of all correspondence by the various men in charge were filed both in their own files and in the General Office. No one, except the heads of the departments, was allowed in the General Office, unless on special business. Prints, drawings, and other data were handled in the same way as the correspondence; except that after being stamped as to date and hour received, they were passed out directly to the proper department.

The stenographic work for the entire office was handled by the one stenographer, who was assisted occasionally by help from outside, when there was a great rush of copying to be done. By means of a buzzer system she was notified when wanted.

The Office Boy attended to all of the filing in the General Office and

were delivered promptly in the
and went on all necessary
of a general nature around the office.
were arranged for by the General Office,
by the department heads—mostly by the
were turned in to the Chief Clerk, who O. K.'d
All payments were made through the
signature of a member of the firm, or, in the ab-
of one of the two principal assistant engineers
purchases and salaries. All cost-keeping and
looked after by that department.

separately under job numbers, which were as-
Clerk. No distinction was made between proposed
construction, although in every other way these two
kept separate.

Department consisted of the Chief Designer with such
required at different times. As a rule, the Chief De-
himself both for preliminary estimates on
the final construction. When unable to turn
time, he secured from the Drafting Department
to complete the work. He likewise obtained
Department for checking the calculations or for pre-
came under his supervision. These consisted
Stress Sheets, and any other drawings affecting
The checking of erection schemes, sent in by the
and the assimilation of other data of a nature
were handled by this department. When men
to take care of such work, they were entirely
till he released them. The Chief Draftsman was
these men completed their work in the Designing
approximate time of such completion was given
he could have work ready for them on their
Department.

drawn up on the special form shown in Fig.
paper was used so that prints could be made.
blue lines in one-quarter-inch squares, every
being red. A title form appeared at the top
beginning of any set of calculations, a data sheet,
first filled out. A yellow color was used for
out conspicuously from the rest of the calcu-
sketch, this sheet gave the complete notes cov-
of the structure, and indicated what speci-
The calculations were generally worked
ing with the floor and following with the
bracing, vertical sway bracing, portal brac-

ing, and trusses or girders. These were followed by special calculations, such as those for counterweights, towers, machinery, etc. The sequence naturally was arranged to suit the particular type of structure being designed. This remark refers especially to the superstructure. In the substructure no such condition exists. The substructure calculations were made either first or last, depending on the demands for getting out the plans for it. Where a separate contract was let for the substructure prior to the letting of the superstructure, the former course was necessary. From the weight curves in the office the superimposed loads were readily figured and the design made. When the superstructure calculations were completed these loads were checked by the actual loads.

For proposed jobs and small constructions the calculations were worked up in a single section. However, on large jobs it was found advisable to break up any one set of calculations into numerous sections for ease in handling and convenience in getting out the work. These sections were arranged to accord with natural divisions in the structure, such as substructure, truss spans, plate-girder spans, trestle approaches, counterweights, towers, machinery, etc., and they were lettered A, B, C, etc. A title sheet, drawn out on the regular calculation paper and giving the name of the bridge and the letter and title of each division, was bound in with it at the front. As these divisions were checked, they were turned over to the Chief Draftsman for the preparation of the drawings. They were filed, as explained later, after the detail drawings were completed. After the calculations were once checked, no notes of any kind (either in pencil or in ink) were permitted to be made on them. Whenever revisions were considered advisable, they were first brought to the attention of the Chief Designer. At a convenient time he looked into them and had them attended to. Every revision made was properly marked, and the mark was given at the top of the sheet, together with the initials of the maker and those of the checker, as well as the dates on which the revision was made and checked. On the white title sheet the numbers of the sheets revised, the fact that they were revised, the initials of the maker and checker, and the dates of marking and checking of the revisions were given. These changes were kept track of by revision blanks shown in Fig. 58c. Whenever a part of the calculations was replaced completely by a later design, all sheets affected were marked "VOID" in large plain letters so as to preclude any chance of their being used. The person who marked a sheet "void" noted thereon his initials, and the date; and a reference to the sheet replacing it was noted when advisable.

After the calculations for the whole job or any section of it were completed, the preparation of the drawings was begun. This procedure was not always followed, as it was sometimes necessary to start the drawings before the calculations were checked. In this case, the Chief Designer had blue prints made for the use of the drafting room. At times this entailed extra work when changes were made in checking; however, modi-

[illegible] this department [illegible] from ten to thirty-five draftsmen [illegible] amount of work under way [illegible] filed of Blueprints completed [illegible] for any length of time, the Blueprint [illegible] work was taken care of by the clerk [illegible] drawings, the making of blue prints, the [illegible]

REVISIONS

[illegible] ....

[illegible] ....

[illegible] SHEET No. ....

[illegible]	DATE	REMARKS

FIG. 58c. Revision Blank.

[illegible] of the department's special correspondence, [illegible] files, indices, etc., pertaining to the work of the [illegible] Departments, were all looked after in this depart-

[illegible] by squads consisting of a Squad-boss and from [illegible] under his direct supervision. With ten or less men [illegible] the Chief Draftsman directed all of the work per- [illegible] special matters to look after himself, he ap- [illegible] take charge of the men for him. It was always [illegible] Squad-boss enough men to keep him busy direct- [illegible] such questions as might arise, in addition to [illegible] work and the laying out of important details. [illegible] up outside of the office, particularly with [illegible] were, as a rule, referred to him. At times he [illegible] to make; and these were reported upon [illegible] Certain correspondence was likewise

[illegible] over to him. The draftsmen were
alone, who assigned them their work; and
instructions by anyone else. When the Chief
[illegible], noted changes that should be made, he
[illegible] on the discussion and then left him to give
the same way any member of the firm, desiring changes
called these to the attention of the Chief Draftsman
their being carried out properly. In all cases it was
the authority and prestige of any individual who
position.

The Squad-boss laid out the work for each man under him,
it throughout its progress. He arranged this so that it
essary for the various men to discuss the details among
it was intended that each man should carry on his work
such matters as required the Squad-boss's attention directly
erally, the Squad-boss settled all important points early
instructed the men as to his decisions regarding them.
ally in the nature of general details or specifications
of more than one man or of special details requiring
in their solution. At all times it was attempted to limit
cussions to the Squad-boss and each individual under him,
between the men themselves were found to be long-drawn
lead to nowhere. For the same reason communication
different squads was limited as much as possible.
were not adopted in this regard, as it was not intended to
the freedom of the men. It was considered advisable,
mine the sources of authority and have these resorted to
Care was always exercised to handle the work economically
least red-tape possible and yet to fix the responsibility of
Moreover, it was practically a necessity to have a quiet,
ing force; and promiscuous discussions did not contribute
Ordinarily, only the checking of detail drawings prepared
was handled independently of the Squad-boss. The
responsible to no one except the Chief Draftsman, in order
being influenced by any one connected with the work.
erty to discuss any detail with the Squad-boss or
to use his own judgment after such a discussion. Only the
man could settle a difference of opinion between the
detail to employ. Occasions sometimes arose when it
to handle certain special investigations outside of the
men carrying on such work were placed under the
the Chief Draftsman.

The squads were not permanent in their organization
essary to arrange them to suit the existing conditions
time. Moreover, it was the purpose of the office

rounded an experience as possible, because this course resulted in benefit to the office as well as to the individual. Naturally, the individual had to be equal to the responsibilities placed upon him or he would not have been entrusted with them. With this system in vogue, different men were in charge of different squads at different times; and the men in the squads were shifted from one to the other as circumstances demanded. As a rule, the abler and more experienced men were made Squad-bosses; although sometimes younger men were placed in charge, particularly when they showed themselves specially fitted to handle men. Likewise the older men were placed in charge of checking work, on account of their experience. Generally, the least experienced men were put on the tracing and the correcting of drawings, while the more advanced ones devoted themselves to detailing; but sometimes it was necessary for the latter also to make tracings. The work was arranged so that a single squad either handled the entire job or took care of one or more divisions of it. The former arrangement was possible on small jobs; but on large ones where the layout was considerably varied, it was necessary to follow the latter course. In this case the divisions were made as complete in themselves as it was practicable to make them in order to avoid the overlapping of details and, consequently, also a division of responsibility between the various squads engaged.

When the calculations on any piece of work were turned over to the Chief Draftsman, he studied them carefully and determined what drawings were necessary and along what lines they were to be worked up. A complete list of drawings was made out at the start so as to obtain a consecutively arranged set of plans. Care was taken to see that there were enough drawings to cover all the details without the necessity of crowding any sheet. This usually called for considerable study, but it was well worth while; for, in addition to producing a logical set of drawings, it gave a working skeleton for the entire job and permitted the making of an accurate estimate of the time and number of men required to turn it out. The Chief Draftsman then arranged for a squad to prepare the plans, and turned over the calculations to the Squad-boss, giving him written instructions as to the handling of the work. The Squad-boss reviewed these thoroughly and then laid out the work for each man under him. He decided upon such details as lacing bars, stay plates, kinds of splices to be used, etc., so as to make the practice uniform; and he determined the amount of detailing necessary so as to avoid any duplication. Special instructions and notes were written so as to prevent any misunderstanding or any excuse for neglect on the part of the men. General decisions of importance were always written and placed on file, and copies were furnished the draftsmen for reference. Small letter-size sheets, 8½″ × 11″, were generally blocked out, giving the details to be worked up and their location on the drawing. These were turned over to the draftsmen, together with the calculations. The Squad-boss also

[illegible] It was [illegible] the men before they got to them. [illegible] the Squad-boss invariably studied [illegible], with the object of securing the best [illegible] for fixing the relations between the web and [illegible] it was frequently necessary to revise slightly the [illegible] calculations in order to secure the desired result, especially [illegible] such revisions, as well as others made by the draftsmen [illegible] were followed the course previously outlined. To [illegible] the drawings quickly, as well as to standardise the [illegible] details and methods of designing them were worked up and [illegible] were given to the draftsmen for use in detailing. [illegible] possible to prepare standards; but, as a rule, the work [illegible] so varied that this was not feasible to any great extent. [illegible] and standard details were drawn out on letter-size sheets. [illegible] A sheet for standard lettering, linework, and conventional [illegible] was prepared for the use of the draftsmen.

Almost all detailing was done on paper in pencil and [illegible] tracing cloth in ink. Certain work was sometimes pencilled [illegible] the tracing cloth and then inked in; but this was the [illegible] than the rule. In the preparation of the pencil drawing [illegible] erally taken to see that it was made exactly as it was [illegible] traced. This was not always the case, however, as it was [illegible] found advantageous to detail on small sheets and adjust them [illegible] ing in tracing them. This system was found convenient in [illegible] a drawing the entire detailing of which could not be done [illegible] either for lack of information or on account of the necessity [illegible] on some other detail not yet determined. Care was always [illegible] that the pencil work was carefully done, so as to give no trouble [illegible] the tracing. If it became necessary to lift the cloth in [illegible] to make out any detail or lettering, it was called to the attention [illegible] detailer so as to prevent a similar occurrence on future work. [illegible] attention was given to the line work, especially in regard to its [illegible] make-up, as the conventions adopted by the office had to [illegible] A pencil sufficiently soft to give a clear, distinct line and yet [illegible] to prevent smudging was used. Certain important lines, [illegible] lines, bounding lines, etc., were frequently inked in on [illegible] cially on heavy work where considerable erasing might [illegible] pected. The location and composition of titles, notes, [illegible] also carefully watched on the pencil drawings, although [illegible] tering was not considered material so long as it was [illegible] After the drawings were traced, the titles, which [illegible]

[illegible] by the [illegible]
[illegible] the drawings [illegible]
[illegible] to save the [illegible]
[illegible] and the approved details [illegible]
[illegible] completed a whole sheet [illegible]
[illegible] with the detailer or Squad-boss. [illegible]
[illegible] of running back and forth as well as the [illegible]
[illegible] concerned. Of course, this practice [illegible]
[illegible] it sometimes happened that such matters [illegible]
[illegible] of the work. In such cases the points [illegible]
[illegible] as they arose.

[illegible] was completely checked, it was returned to the
[illegible] over to the detailer for back checking. The
[illegible] and, when through, took up with the checker
[illegible] agree to. These differences were then settled
[illegible] when no agreement could be reached, the point
[illegible] the Squad-boss and, if necessary, to the Chief
[illegible]. After this, the tracing was corrected in accord-
[illegible] and returned to the checker. He then ticked
[illegible], comparing it carefully with the checking
[illegible] changes had not been made, these were noted on
[illegible] returned for further correction. Finally, after it
[illegible] signed by all parties connected with it where indi-
[illegible] The checking prints likewise were signed by all par-
[illegible] the dates on which the checking, back-checking,
[illegible] done were added. The checking prints and the pencil
[illegible] away until the shop drawings had been approved,
[illegible] destroyed. This was done merely for reference in
[illegible] errors in the drawings. As far as it was pos-
[illegible] was given the checking of an entire job or a defi-
[illegible] to fix the responsibility for the work. Where
[illegible] on one job, they were expected to compare over-
[illegible] be certain that no differences occurred on that
[illegible] likewise watched this particular point in
[illegible]ailing.

[illegible] in the detailing and checking of drawings were
[illegible] books containing 150 sheets about 10″ × 12″
[illegible] quadrille ruled in one-quarter-inch squares,
[illegible] suitable for this particular work. Each in-
[illegible] proper title, and each day the date was put on
[illegible] Each book was indexed for ready reference.
[illegible] the draftsmen at their desks until they were

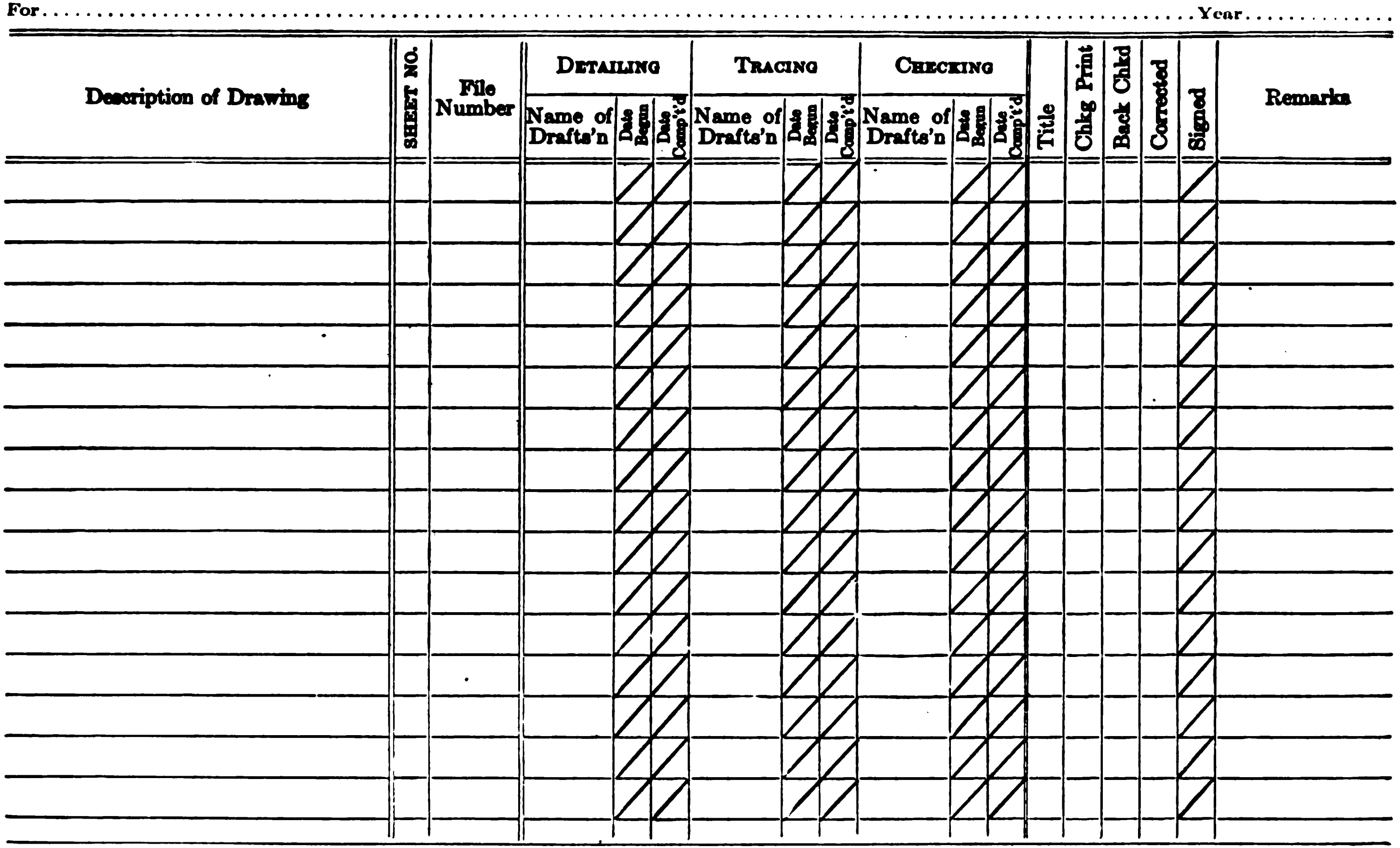
of no further use to them, when they were filed in a convenient place in the drafting room.

Although the standard sheet, 28″ × 37″ inside and 29″ × 38″ outside of the border, was mostly used for drawings, half-size sheets, 18″ × 28″ inside and 19″ × 29″ outside, were sometimes found convenient. Moreover, during the checking of the shop drawings and during the construction of the job, it was frequently necessary to send out a small sketch of a detail. For this purpose a letter-size sheet, 8½″ × 11″, was employed. The structural drawings were numbered 1, 2, 3, etc.; the mechanical drawings, M1, M2, M3, etc.; and the sketch sheets, D1, D2, D3, etc. Whenever a tracing was replaced by another, the original one was marked "VOID" in large letters near the title, with a note, "See final drawing No. ———." The new drawing took the same number as the original except that the letter A, B, or C, was added to it as a distinguishing mark to signify the number of times the drawing had been remade.

A concise record of the detail drawings was kept for each job on the form shown in Fig. 58*d*. The sheets were 10½″ × 16″, the same as those used for the calculations; and they were punched at the left hand end for a canvas-backed folder made specially for the calculation file. These records were placed in the folder in alphabetical order according to the title of the job, and were kept by the clerk. As soon as the list of drawings was made up, the above form was filled out to this extent. Then as the drawings were gotten under way, the record was extended until it was complete. The data for this were taken from the time-cards described later. The squares in the columns listed "Title," "Checking Print," "Back Checked," and "Corrected" were merely checked thus (√) when any of these items had been taken care of. By referring to this record one could see at a glance just where any particular job stood at any time.

After the tracings were checked, reference prints were made and turned over to the Squad-boss; after which the tracings were filed in the cabinets used for that purpose. These prints took the place of the tracings to a large extent, as otherwise the wear and tear on the latter would soon have put them in bad condition. They were used in the checking of shop drawings and in general reference work. Moreover, all important corrections, made after the drawings were first signed as being checked, were noted on these prints as a record of the same. These changes may have been due to the shops, to the owners, or to the office itself. These prints were kept until the job was completed in the field, after which they were destroyed. No pencil marks or notes of any description whatsoever were permitted on the tracings after they were checked. Where corrections were necessary, they had to be called to the attention of the Chief Draftsman, who saw that they were taken care of in the proper course.

The work of checking the shop drawings was turned over to the men



For...Year...............

Description of Drawing	SHEET NO.	File Number	Detailing			Tracing			Checking			Title	Chkg Print	Back Chkd	Corrected	Signed	Remarks
			Name of Drafts'n	Date Begun	Date Comp't'd	Name of Drafts'n	Date Begun	Date Comp't'd	Name of Drafts'n	Date Begun	Date Comp't'd						

FIG. 58*d*. Drawing Record.

who made and checked the detail drawings, if they were available for this purpose. The shop prints were sent in in duplicate, one copy being for the office and the other for the shops. Only such items as the principal dimensions, sections, details, and strengths of all parts were checked. The rivet spacing was not looked into except to see that no spacing less than the minimum or greater than the maximum allowed by the specifications was used. Net sections were carefully watched for any improper reduction by the shops. The number of field rivets was checked in all cases; but the matching of field connections was not looked into. The shop lengths of all main members were checked, and the lengths of a few bracing diagonals were figured to see that the shops were giving them the proper draw. Items that affected the shops alone, but did not influence the strength of the structure, were not investigated. The checkers were instructed, however, to see that the details for the structure were complete and that the proper number of each was ordered by the shops. A point that often gave trouble in the checking of shop drawings was the fact that the shops frequently made corrections other than those noted by the checker without calling attention to them in any way. This was immaterial, of course, in unimportant details; but the fact that some important detail might be overlooked through this course led the Chief Draftsman to instruct the shops at the beginning of each job to underscore all such changes, no matter how unimportant they might be. This was found well worth while on more than one occasion. As far as possible, the corrections were made so fully on the shop drawings and in such a manner that the reasons for them would be evident to the shops. Where this could not be done, the correspondence was made to clear up the changes. The shop prints were stamped "Approved" or "Approved as Corrected" and signed by the checker, who also added the date of checking. They were then returned with a letter of the form shown in Fig. 58*e*, except where it was necessary to advise more fully regarding the corrections, in which case a special letter was written and enclosed with the form letter. The latter was made out in triplicate by the checker, the original being for the shops and the copies for the Drafting Department and the General Office. These three copies were turned over to the Drafting Room Clerk, together with the prints, which were divided into the office and the shop sets and so marked. The clerk checked the prints against the list given in the form letter, and approved the latter, if found correct, by adding his initials where noted "Approved." The shop prints and the letters were then turned over to the general office for mailing. After this the office prints were recorded by the clerk and filed, as were also the copies of the letters.

All drawings were mailed in duplicate by the shops, until approved; and when approved, final prints were sent in for the files of the Field Engineers, the Shop Inspectors, the Clients, and other parties to whom sets of drawings had to be forwarded. These prints were all stamped

"Approved," and were forwarded with the form letter shown in Fig. 58*f*, being handled in the same manner as the prints returned to the shops.

WADDELL & HARRINGTON
CONSULTING ENGINEERS
KANSAS CITY, MO.

____

______________________BRIDGE

____

____

SIRS:—We are returning you to-day prints of your drawings as follows:

Contract No.	Drawings Approved	Drawings Approved as Corrected

APPROVED:

____

Yours truly,
WADDELL & HARRINGTON
By______________________
Chief Draftsman

FIG. 58*e*. Form Letter Accompanying Shop Drawings Returned to the Contractors.

At the close of the job a final set of cloth prints was obtained from the shop for a permanent record.

A complete record of the shop drawings was kept on the form shown in Fig. 58*g*. These sheets were of the same size and were filed in a folder in the same manner as those for the record of the office drawings. The

drawings were always listed consecutively, and the sets thereof for the various contracts on any job were kept separately. The shops were requested at the outset of a job to furnish a list of their drawings for the

WADDELL & HARRINGTON
CONSULTING ENGINEERS
KANSAS CITY, MO.

____

____________________BRIDGE

____

____

Dear Sir:—We are sending you to-day, for your file, prints of shop drawings for the above bridge as follows:

Contract No.	Drawings (Give Number of Prints)

Yours truly,
WADDELL & HARRINGTON
By..................................
Chief Draftsman

APPROVED:
....

FIG. 58*f*. Form Letter Accompanying Shop Drawings sent to Clients, Resident Engineers, Inspectors, etc.

whole work or any section of it at the earliest date possible in order to assist in arranging the record. It was not always convenient to do this; but when it was done, it certainly was a great help to the office.

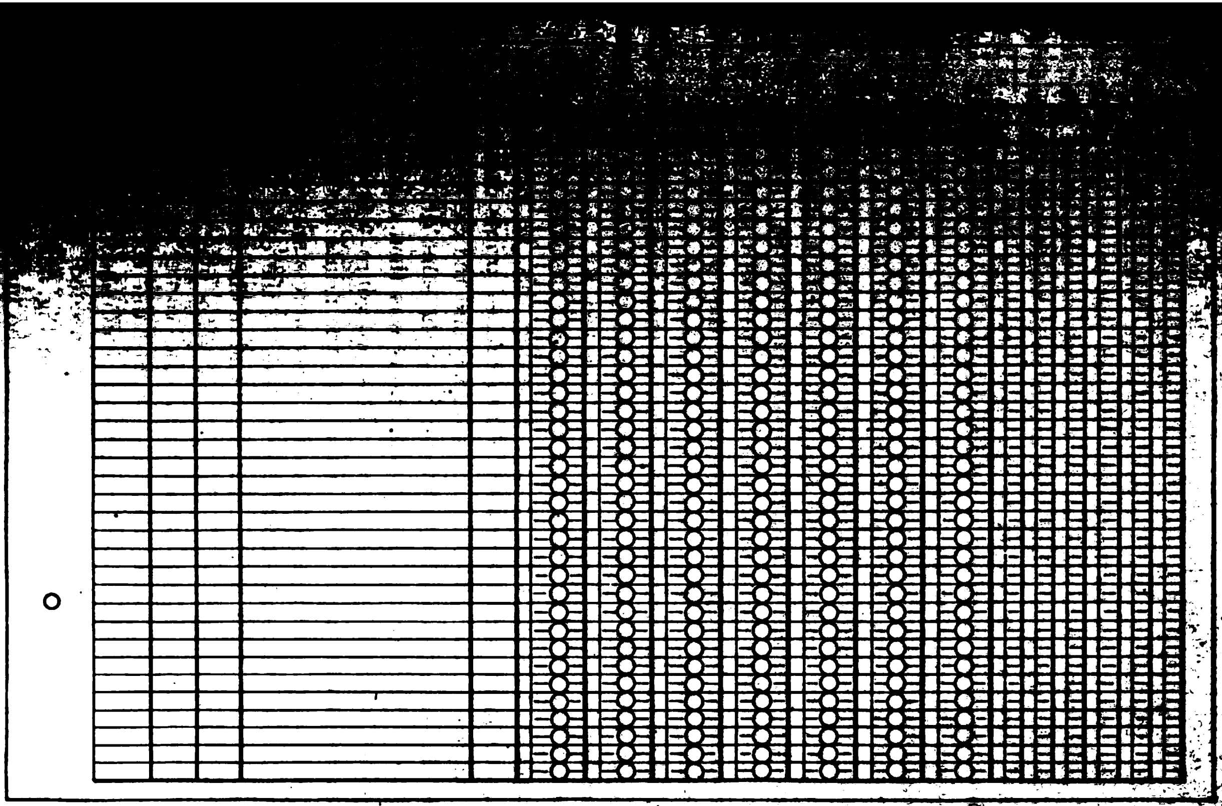


FIG. 589. Shop Drawing Record.

[illegible] Department, a file [illegible] was filled out as to the name of the bridge, the [illegible] contract number, the sheet numbers, the file [illegible], the number of prints of each drawing received [illegible] receipt. The last two items were placed in the column [illegible] By," the first in the rectangle and the last just to the [illegible]. The prints were then assigned to the checkers, who [illegible] them immediately, unless they had more urgent work to get out. It was always planned, however, to attend to the shop drawings just as soon as they reached the office, so as not to hold up the shop work or to give the shops an excuse for claiming an extension of time. To assist in this respect, the clerk went over the records of unfinished jobs each week and made out a list of prints that had been held in the office a week or more. This list was turned over to the Chief Draftsman, who investigated the reasons for the holding up of the work in question and made sure that the checking was not thereafter unnecessarily delayed. A similar list was made of drawings being held unduly by the shops, and a copy of this was forwarded to them with a request that they push the work as much as possible, when the work was likely to get behind.

As soon as the drawings were checked, they were turned over to the clerk, as previously noted. He then inserted the names of the checkers in the key and their initials under "Checked By." In the circle he wrote "A" or "C," depending on whether the drawing was "approved" or "approved as corrected"; and following this, he gave the date on which the prints were returned. When revised prints came back, these were entered in the next column as before, and the clerk delivered them to the checkers, together with the prints of the same drawings previously received. The checking of the corrections was then taken care of, and the prints returned to the shops. This procedure was continued until the drawings were approved. After that, the prints for the various files were sent in by the shops and listed. They were stamped and forwarded to the proper parties, a record being made of the date and the [illegible] of prints sent to each at the right-hand end of the sheet under [illegible] ing "File Prints Sent To." The year or years over which [illegible] tended were given at the upper right-hand corner of the [illegible] the record was complete, the upper right-hand corner was [illegible] noted, for convenience in referring to the unfinished jobs.

When prints of the office tracings were needed, orders for [illegible] made out in duplicate on the form shown in Fig. 58h, consisting [illegible] sheet 8½" × 11" in size. This form gave the number and [illegible] of each drawing wanted. They were placed in separate [illegible] the blue-printer and one for the Drafting Room. The [illegible] his copy, picked out the tracings, and made the prints. [illegible] copy, together with the prints, to the clerk, who made [illegible]

[illegible] and the other [illegible] in the [illegible]

[illegible] had to state clearly the purpose [illegible] were to be sent out of the office, they were [illegible] turned over to the General Office, together

Date..............................

[illegible]MAN:

[illegible] Prints:

Ordered by..............................

[illegible] Herewith.

Date..............................

Signed..............................

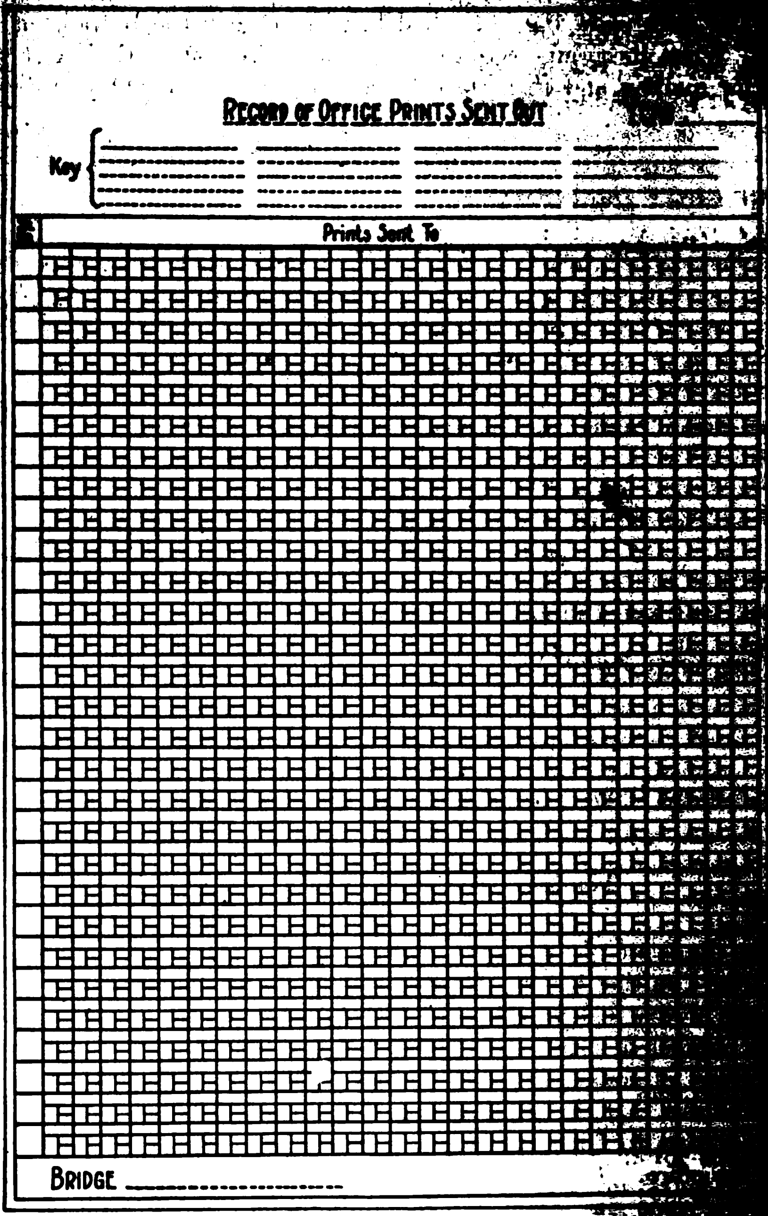
....

Signed..............................

Order Blank for Blue Prints.

[illegible] order, properly signed. The original order was [illegible]. In preparing prints for mailing in envelopes, [illegible] that the titles appeared on the outside. When [illegible] were ordered at one time, the more important [illegible] attended to first. This was looked after by the [illegible] were gotten out as quickly as possible.

[illegible] orders, a record was kept of all prints sent [illegible] were listed on the form shown in Fig. 58*i*, which [illegible] standard calculation sheet and was kept in [illegible] made out for each job; and these records [illegible] according to title. The sheet numbers were [illegible] numerical order, even though prints were not [illegible] initials of the party to whom the prints were



RECORD OF OFFICE PRINTS SENT OUT

Key

Prints Sent To

BRIDGE ____________________

FIG. 58i. Record of Office Prints Sent Out.

rectangle, the number of prints below to
to the right. The key gave the full names
initials used in the record. The year or years
the sheet, and the name of the job at the bottom.
directly from the orders at the earliest con-
prints were sent out.

TIME CARD

....................DATE....................................

Work	Hours	Remarks

FIG. 58j. Daily Time Card.

ndling as well as the making of complete records
card, 3″ × 5″ in size, shown in Fig. 58j, was used.
in a card each day, noting upon it the jobs he
numbers of the drawings; the section numbers
contract numbers of shop drawings; the nature
ing, tracing, checking, back-checking, correcting,
spent on each; and any remarks that might be
plete record. In all cases in the "Remarks"
a piece of work was started or completed. The
by the clerk on the "Monthly Time Card,"
sheets were 8½″ × 11″, punched for a loose-
assigned to each job, and these sheets were
bers. The time per man per job was totaled
these totals were added together and checked
man taken from the daily time cards. The
nded in to the General Office for cost dis-
ds were filed in the Drafting Department.

JOB NO. MONTHLY TIME CARD MONTH

HOURS WORKED BY

Date																													
1																													
2																													
3																													
4																													
5																													
6																													
7																													
8																													
9																													
10																													
11																													
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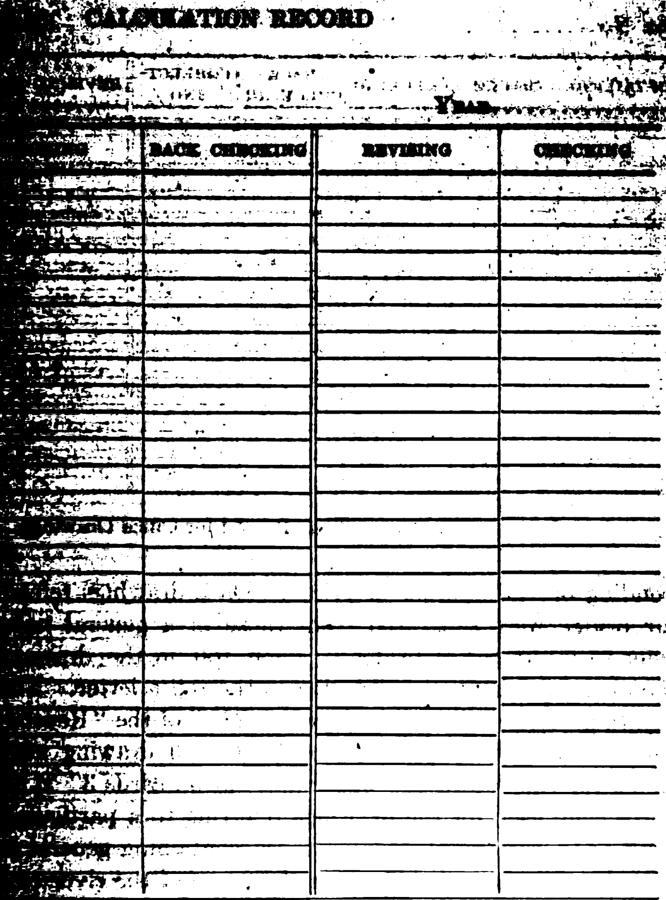
20																													
21																													
22																													
23																													
24																													
25																													
26																													
27																													
[illegible]																													
[illegible]																													
[illegible]																													
[illegible]																													

[illegible] A file card was also [illegible] not be assigned to any definite item. [illegible]


CALCULATION RECORD

YEAR

[illegible]	BACK CHECKING	REVISING	CHECKING

[illegible] Time Record for Calculations.

[illegible] "General." These cards were all filed in [illegible] the job numbers, in a standard filing case. [illegible] for them were maintained in the Draft- [illegible] the six drawers in the drafting tables were [illegible] to the cases made specially for that purpose. [illegible] in charge of all of these. Capital letters [illegible] the different files, and the drawers in each

The Record Drawings were filed in the sisted of all drawings containing data or whatsoever sent to the office by clients, field account of the irregularity in the sizes of the sheets, all drawings pertaining to one job being placed in

DRAWING RECORD

Job No........... Sheet No........

DETAILING	TRACING	CHECKING	BACK CHECKING	CORRECTING	REVISING	CHECKING	[illegible]

FIG. 58m. Time Record for Office Drawings.

pending on the number of prints. Data drawings referring to a lar bridge were separated from those of a general nature which refer to a number of bridges. Each roll in the drawer was given a ferent number and each drawing in the roll a letter. Thus R16-5c drawing "c" in roll "5" in drawer "R16" of the "Record File." number was written on the back of each drawing at both ends. index for the record file was made out on cards 3″ × 5″ in size. cards were used for the drawings referring to a particular structure, pink ones were employed for those containing general information The drawings were listed under the name of the river or detail, referenced under the name of the client, city, and street. The given on the main card was always sufficient to designate the for reference. In using any drawing, the whole roll was taken the file by the person wanting it. This was returned to the saw that the roll was complete and in order; and then he the file.

The calculations were filed in folders, as noted previously posed and the final jobs were placed in separate folders, marked PB1, PB2, etc., and the latter C1, C2, etc. bridges were filed together in the same folder, while

folders. This was gauged by using a scale

and one-half inches to one set. The divisions

designer were maintained in the filing. A complete

the sheet numbers were given at the beginning

the folders for small bridges, each set of calcula-

SHOP DRAWINGS

Year............

[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			

Time Record for Shop Drawings.

labelled; in the large bridges, the main divisions, "Spans," "Towers," etc., were likewise tabbed … tions were indexed under the name of the river … indexed under the name of the client, city, … ber of the folder and that of the main division, … signed to a single job, were given. Standard … ployed.

… detail drawings were filed flat in drawers

[illegible] of a standard vertical filing [illegible] envelopes about ten to each drawer, each [illegible] drawings. These were arranged in numerical [illegible] envelopes were printed the title of the job and the numbers [illegible] they contained. The mechanical drawings were kept in a [illegible] tion of the cabinet. All void tracings were placed in a [illegible] the bottom of the drawer, so that only the final drawings [illegible] the regular file envelopes. Proposed jobs were kept [illegible] final jobs in a special section of the case. Small [illegible] miscellaneous sheets were likewise filed in special drawers. [illegible] was necessary to make extra long drawings for the "General [illegible] certain structures, and these were rolled and placed in [illegible] separate from the rest of the set. The small sketch sheets were [illegible] paper folders in alphabetical order according to the name of [illegible] While the draftsmen were permitted to remove tracings from [illegible] they were not allowed to return them. Instead, they were [illegible] special drawer, assigned for the purpose, from which they were [illegible] and properly distributed each day by the clerk. This was done [illegible] to hold the clerk responsible for the order of the files.

The index for the tracing file was made out on the standard [illegible] cards. The jobs were listed under the name of the river or [illegible] subject, and were cross-referenced under the name of the [illegible] and street, and also under any other heading by which it might [illegible] nized. The drawings were all listed and grouped under the [illegible] classifications: General Drawings, Substructure, Stress Sheets, [illegible] structure, Miscellaneous, and Void. Maps and General [illegible] recorded under "General Drawings"; while all miscellaneous [illegible] included under "Miscellaneous." On large bridges the above [illegible] tions were still further broken up according to the main divisions [illegible] structure. The cards for any job were not made out until after the [illegible] ings were completed.

The Checking Prints were folded and put away in a vertical [illegible] the shop drawings were checked, after which they were destroyed. [illegible] were kept in alphabetical order, but no index was provided for [illegible] Prints sent to the clients for approval were filed in a similar [illegible] when returned. They were destroyed after the job was finished [illegible] completely settled for. When prints were sent out to bidders, an [illegible] tical set was filed in a vertical filing case and kept until the [illegible] was completed. They were then destroyed. They were used if [illegible] a dispute arose regarding the plans upon which the bids [illegible] based.

During the construction of a job, the Resident Engineer [illegible] office records of the structure as actually built. These [illegible] vertical filing case. At the end of the work a drawing [illegible]

in the table drawers under the They were arranged in consecutive order placed in the final set. All void or replaced in proper order at the bottom of the drawer. the job was finished in the field and all claims destroyed, all except the cloth set, which was bills and small sketch sheets were placed in in the same manner as were the regular were permitted to take the shop drawings just as in the case of the tracings, the clerk order. A card index was provided for the shop listed under the name of the river or principal made out only for the various contracts; and merely of the drawing numbers was given, main divisions of the structure were noted. For the "Record Book for Shop Drawings" was for current jobs was kept in the Draft- was made of these, as the General Office had file.

in relation to drawings were filed in paper jobs. When any job was completed, the special destroyed. A vertical filing case was main- instructions made by clients.

manufacturers were filed in the Drafting Depart- index was made for them.

in charge of the library, and requisitions had to secure library books. The person signing these books taken out until they were returned.

value concerning office practice can be found valuable work on "Plate-Girders," and in on "Engineering Office Systems."

CHAPTER LIX

INSPECTION OF MATERIALS AND WORKMANSHIP

BEFORE commencing to prepare this chapter, the author took the precaution to write several of the leading inspecting bureaus of the United States and ask them for comment on Chapter XXI of *De Pontibus*, which also treats of the subject herein considered; for he knew that during the eighteen years which had elapsed since that book was written many important developments in American methods of inspection had taken place. The result was the accumulation of much valuable material concerning the inspection of metalwork from such high authorities as Messrs. Hildreth & Co., the Pittsburg Testing Laboratory, Messrs. Colby and Christie, C. C. Schneider, Esq., C.E., E. McLean Long, Esq., C.E., and Robert W. Hunt and Company. This has been utilized in recasting that portion of *De Pontibus* relating to metal and metalwork inspection; and the author here takes the opportunity to express to those gentlemen, individually and collectively, his sincere and hearty thanks for their kind cooperation and valuable aid. In some places he has quoted verbatim from their contributions with the usual due acknowledgment, but in others he has applied the information and suggestions directly to the modification of his own previous writings.

Unless all the materials used in a structure and all workmanship during the various stages of manufacture at the shops and of construction in the field be subjected to competent and honest inspection, much of the benefit obtained by scientific design and thorough specifications will be lost. For many years most of the inspection of structural metalwork was a sad farce; and, in consequence, the general public placed but little confidence in inspection, with the result that a large portion of the bridgework of the country was left entirely to the tender mercies of the manufacturers, who naturally worked for their own interest and not for that of the purchasers. Of late years, however, improvements in inspection methods have been made by a few of the leading specialists in that line of work; but, sad to relate, there is still a vast amount of slip-shod inspection being done at rolling mills and bridge shops, mainly because purchasers of metal are not willing to pay a proper compensation to the inspectors. In times past the author suffered considerably from bad inspection in such matters as the insertion of a rust-joint in a turntable between the bottom of drum and top of upper-track segments, where no such filling was allowed in either plans or specifications; badly matching holes in field connections; pin-holes too small for pins; important members

made longer than called for by the draw-
and fillers at ends of girders; and shop-paint
of frozen mud. Such things, to say the least,
and often cause great expense during erection.
has adopted the policy of having all of his metal-
by one firm, with the result that all the glaring
of engineering work have been cut out, probably
that the annual amount of structural steel emanating
has amounted to many thousands of tons, and, in
bureau did not want to lose a good job.
no means entirely to blame for the fact that the
steel in general is not what it ought to be; be-
the railroad managers and promoters of large en-
the necessity for first-class inspection, and
to pay one-half of what such inspection is worth.
the inspectors are to blame, for the reason that in
competition for work they have cut prices to such
impossible to do proper inspection without losing
down to facts they have to confess this. The
the "small fry" inspectors is often amusing. The
over the coals by one of this class who had put
inspection, and whose tender had been rejected
the work having been awarded to one of the
at about fifty per cent more than the unsuc-
After expressing his mind pretty freely, he fired
I never intended to do thorough inspection for

has been utterly demoralized in times past by
contemplated by this inspector; for it was the
yet to a certain extent with some inspectors, to
at whatever figures the purchasers are will-
the work so as not to lose money on the contract,
the interests of their employers. Strange tales
to the ears of engineers—such, for instance,
car-load of metalwork that was not seen by the
for shipment; but such tales need verifica-
nobody's business to give. There is no doubt,
being authentic. In one case in the author's
his work for ten days in charge of one of the
clerks, without notifying either the author or
inspection bureau, of his contemplated absence.
entertain serious doubts sometimes as to

demoralization of metal inspection by
competition has lowered the quality thereof

to such an extent that even the highest possible prices would not make it, for some time to come, what it ought to be; because not only are the assistant inspectors lacking in proper training and thoroughness, but the manufacturers have become accustomed to a certain class of inspection, and would deem it a hardship to be subjected to much more rigid requirements. Eventually, however, the resulting improvement in manufacture of metalwork would be an advantage to the manufacturers as well as to the purchasers.

A decided betterment of inspection can be brought about only by concerted action on the part of the principal inspecting bureaus and inspectors of the country, backed, of course, by the aid of all engineers who are directly interested in the designing and building of structural metalwork. If these inspecting bureaus and inspectors of established reputation were to form an association for the purpose of determining what inspection should consist of, and what minimum rates should be charged therefor by all members of the association, and if admission to the association were based upon both experience and good faith, it would be practicable to make very quickly the improvements requisite for bringing inspection up to an almost ideal standard of excellence. For a while a good deal of work would go to the inspectors outside of the association; but ere long the general public would become educated to the fact that good inspection of metalwork is a necessity, and that it can only be obtained by paying living prices to those who do the work. Engineers, in order to aid in the good work of the association, should refuse to include the price of inspection in their fees for engineering work, and should make it a rule to employ for doing their inspection only members of the association.

Certain engineers of high standing have spoken slightingly of this proposition to form an association of inspectors, terming it a "trust." Strictly speaking, it certainly would partake of the nature of a trust, but it would be a good and worthy one, the main object of which would be to effect a much needed reform. On the same basis the American Institute of Architects is a trust, for the reason that it establishes a minimum fee of six per cent for the making of plans and specifications and sometimes also for the services of an inspector on all building work; and surely such an organization should not be condemned on this account. On the contrary, the architects have set the engineers a good example in forming this association; and, until engineers follow their lead in this particular and establish minimum fees for professional work, the engineering profession will fail to attain its highest degree of efficiency, and will, therefore, not be properly recognized as a profession by the general public.

In order to present the inspectors' views on the subject of metalwork inspection, the following quotation is extracted from a communication by Messrs. Hildreth & Co.:

progress. The supervision of the
of checking the design and
is rarely necessary
It is fair to assume that all
good value under their contracts, and
the policy of constantly and
However, when the details of manufacture are
that practically all work is piece-work, and
strong personal interest in the high character of the work
careless, but they have a personal incentive to do their
constant pressure of their superiors to 'get out the ton-
the workmen that requires thorough and careful inspection;
attitude of the managements of a great majority of manu-
when it is done by an intelligent and experienced
as to discover defects and errors as early in the
with the management as to the output of good
to the manufacturer.

the supervision of manufacture is the value of having a
of manufacture, whereby the progress of the work is known
product can be had at the time and in the order
economical erection.

supervision by inspection is in having a record whereby
workmanship is attested to and may be useful in placing
possible failure or in relieving from responsibility
properly be relieved from the same. It is not inconceivable
who fails to provide for the supervision of manufacture
damage or loss of life resulting from any failure at erection

CTIONS OF THE INSPECTING ENGINEER

manufacture may be made by employees of an Engineer or
of Inspecting Engineers who make a specialty of such
existence of the latter are primarily that the manufacture
conducted at various rolling mills and at one or more fabri-
several points at the same time, and is frequently inter-
tect uses his own employees for this work, it is essential
and there is, consequently, much waste of time and of
this situation, the independent Inspecting Engineer estab-
men who are permanently located at the various
by competent supervision of their work, makes use of
contracts, thereby tending to efficiency and economy.
has a wide knowledge of shop methods and a personal
managers, and from experience is able to handle the
with some advantage of practical knowledge, as
Engineer, and has personal acquaintance and constant
management.

inspection is not insurance. The inspector is not
sufficiency of tests, or the shop management,
it is to see and report conditions and to conduct
improve the character of the materials and workman-

ship, and give an accurate record thereof. The responsibility for compliance with plans and specifications and general good practice rests primarily with the Contractor. The responsibility of an inspector is for intelligent and faithful supervision and accurate record in accordance with the established and specified practice of tests and standards of workmanship.

"The position of the inspector is that of an employee to the Engineer or Architect, who, when he uses such employee, is himself Inspection Engineer as well as the designer and supervisor. If Inspecting Engineers have charge of the work, they are the Associates of the Engineer or Architect in something of a professional capacity. In either case the quality of inspection is evidently dependent, as is all professional work, upon the character of the men on the work; and it is unavoidable that the character of the men is dependent upon the compensation allowed.

"QUALITY OF INSPECTION

"From the above it will be appreciated that the quality of inspection must, according to the same rule as applies to all business, be in direct proportion to the compensation. To be of genuine value, inspection must be constant, intelligent, and complete. A final inspection may determine the satisfactory compliance with the contract, but cannot, generally, secure the satisfactory correction of errors, and certainly cannot prevent them or tend to the improvement of the work. The tests of quality of inspection are the experience of the men directly on the work, the time spent on it, and the quality of the final record. These tests apply equally to the work of direct employees and to that of Inspecting Engineers. The latter may properly make a profit from the favorable combination of work at rolling mills and fabricating plants or manufacturing shops, and from the saving of time and traveling expenses; but any profit from the neglect of work by insufficient attention or from the employment of underpaid employees is improper. The Architect or Engineer, if he desires to secure the best inspection by Inspection Engineers, should decide upon the experience and reputation of the firm with whom he proposes to deal, should know the experience of the men to be employed upon the work, and should critically examine the character of the record furnished him. He may properly demand information as to the time of the men employed upon the work.

"METHODS OF PAYMENT

"The usual method of payment for inspection services when done by Inspecting Engineers is at a price per ton. This always should be per ton of material or workmanship inspected and not per ton accepted, for the reason that it is undesirable to put a premium upon the acceptance of work which may be defective or doubtful. With knowledge as to the quality of inspection, as noted above, the method of payment by tons inspected is satisfactory; but if an Engineer or Architect is doubtful as to the character of the work that is to be done, he may arrange his terms on a basis of the cost of the actual time of the men employed on the work, plus a percentage to the Inspecting Engineers for organization and supervision. The last course he should take is the placing of inspection work under competition to the lowest bidder. Such a course must mean not only his willingness but his demand for the least attention by the lowest salaried men available. This method is a favorite one followed by Purchasing Agents of large corporations; and it is invariably unsatisfactory. A moment's consideration will convince any one that the proportion of profit to inspectors must remain the same or increase, whereas the proportion of loyalty and conscience must diminish. Payment for inspection is not a part of the obligation of the Engineer or Architect, but is that of the Owner. The strong Engineer or Architect will not evade this question, but will either demand that the Owner make such provision and leave to the Engineer or Architect the right to choose his associate; or he will provide in the specifications that the

Contractor as a part of his work, but shall be arranged at a specified price, and that the Inspectors shall be or Architect."

author's general instructions to his inspecting spection of metalwork at mills and shops.

fully the Engineer's drawings as soon as they are a list of special points and features that will re- shops to secure good workmanship and proper typewritten report of these and submit it without

fully, as soon as they are finished and approved, to become thoroughly familiar with the entire

metal of uniform character and of the strength, specified is furnished by the rolling mills, follow- process to another from start to finish, and making broken represent correctly the metal they are

chemical analyses of the metal occasionally, so as properly made, taking care that the Contractor is piece the samples are taken from, so that he can so desire.

the various tests indicated in the specifications are number of same depending upon the relative uni- furnished.

that all the punching is done with such care that will come together so as to cause the rivet-holes to when the reaming is finished there shall be no

that all pieces are cut to exact length and proper angles bear perfectly at top and bottom that there are no loose rivets.

rivets with flattened heads or countersunk rivets that they are properly chipped or otherwise sions; also see that the ends of all members are the last rivet or pin hole shown on the attention to the ends of all posts and chord- "over-all" and the clear dimensions between to those indicated on the drawings.

means of ensuring that the entire work without difficulty during erection, and so conform in every particular with the Engi- plish the same, it be necessary in special at the shops.

punching and the handling of the metal

in the shops, so as to see that no cracks develop therein, and that it withstands properly the manipulation, showing as perfect homogeneity as is found in the best structural steel.

Eleventh. Condemn, as soon as it is discovered, any material unfit in the slightest degree for use in the structure, no matter how many times it may have already been inspected and passed.

Twelfth. See that all metalwork is properly cleaned by the most approved methods and apparatus before the first coat of paint is applied, and that the latter is allowed to dry thoroughly before the metalwork is loaded on the cars for shipment. It is of vital importance to the life of the construction that the metal be cleaned effectively and thoroughly dried before applying the paint; and the Inspector should at all times use the utmost vigilance to make sure that this is accomplished.

Thirteenth. See that all shop painting is thoroughly done, and that proper paint, mixed so as to comply with the specifications, is invariably used; and make an occasional chemical analysis of the paint, taking care that the Contractor is notified of the contemplated test after the samples are taken, in order that he may make a check analysis, if he so desire. Take special care to prevent any pieces of metal from being riveted together, unless the contiguous faces be first thoroughly painted.

Fourteenth. Should any employee of the Manufacturing Company wilfully violate or continue to violate the specifications or the instructions of the Engineer or his Inspector, bring at once to the attention of the said company the fact of his so doing and request that he be discharged from the work in question; and if the request be ignored, report fully in writing or by telegram concerning the matter to the Engineer.

Fifteenth. While endeavoring in every possible way to obtain good work, avoid as much as possible doing anything to annoy or harass the Contractor; but, on the contrary, take special pains to aid him in every legitimate manner to finish his work quickly and inexpensively.

Sixteenth. Formulate and prepare for each large piece of work the best practicable method of recording progress and reporting thereon, and divide up the total work into groups or sections so that the notes may be easy for reference. This should be done by the inspecting bureau, and should not be left to the shop inspector.

Seventeenth. Send into the office of the Engineer regular weekly reports concerning the progress of the work, any special reports that from time to time appear to be required, the tabulated results of all tests of materials, and copies of all shipping bills.

Eighteenth. Make sure that all shipping weights are correct by seeing the metal weighed, and keep account of the weight of all metal sent out on the work, as the Contractor will be paid by the pound. It will be necessary for the inspecting bureau to check all of these weights against the shop drawings to show how they agree or disagree. A detailed statement of both sets of weights must be sent to the Engineer upon the com-

[illegible] bureau shall, [illegible] work of any kind to [illegible] are to be broken in, they must [illegible] way as not to jeopardize in the slightest [illegible] of workmanship.

[illegible] and in short, do all you can to make the struc- [illegible] the word a credit to all concerned in its [illegible]

[illegible] are those from a consulting bridge [illegible] bureau, and are of a more general nature and, [illegible] than those from such a bureau or an inspect- [illegible] in the rolling mills and bridge shops. In order [illegible] the author, notwithstanding the risk he thereby [illegible] of a certain amount of repetition, reproduces [illegible] instructions of Mr. Long to his assistants at mills [illegible] good ones of Messrs. Hildreth & Co., and of [illegible] & Co., and supplements them with certain [illegible] instructions by Messrs. Colby & Christie (as pre- [illegible] engineer, Mr. Schneider). A perusal of all these [illegible] to post the reader thoroughly as to all the [illegible] inspection at rolling mills and bridge shops. [illegible] read as follows:

[illegible] mill and shop work the Inspector should know what faults [illegible] and when to find them. He should be thoroughly con- [illegible] the shop or mill in which he is inspecting, and should [illegible] to follow the work in all stages of its progress and know [illegible] department.

[illegible] defective material or bad workmanship, the better it is, [illegible] He should make a point of knowing the duties of the [illegible] shop; and he should take up points relative to his work [illegible] with the proper persons and in the proper way, and should [illegible] given and carried out.

“Mill Work

[illegible] for character of steel, and mark anything in them [illegible] extra work on the part of the mill to live up to. Consult [illegible] on such points, and have a clear understanding of [illegible] begins.

[illegible] specifications, showing physical and chemical require- [illegible] Engineer for the determination of the same. This [illegible] Inspector's note-book for ready reference.

[illegible] supply the Inspector with a copy (in duplicate) of [illegible] estimated weights and all information necessary

to enable the mill to fill the specifications. When the Inspector receives these, he should see that the proper information is on them; and he should look over them in connection with the drawings, and should note on the sheets in what part of the structure the material is to be used. A good many draughting rooms make a practice of putting on each order sheet the part of the structure for which the material is intended. This is a good practice; it gives the draughting room very little extra work and facilitates the checking of the material and reference thereto.

"The Inspector, by knowing where material is to be employed, is in a position to use some discretion, and he will not reject material such as filler plates, stiffeners, and the like on account of their being slightly out in some of the requirements. Work is often needlessly delayed and great inconvenience occasioned by the rejection of material that is better than the work it has to do requires. On the other hand, he will mark on the order sheets the material on which the life of the structure depends, and will insist on its filling the requirements in every respect.

"3. *Know the System of the Mill.*

"The Inspector must know the system of work of the mill, and must satisfy himself that the methods employed are such as to prevent the mixing of heats, and that they will insure the knowing of the heat of the finished material. Some mills keep a very close and exact track of all heats used, while others are inclined to be careless. If the methods employed by any mill are not sufficient to keep the heats straight, the Inspector should work with the Superintendent to better his system, or should follow this part of the work closely himself, so as to insure the accuracy of final results.

"4. *Selection of Tests and Identifying Material.*

"The Inspector should determine from the mill what material for his work is rolled from each heat, and should then select tests so as to represent the different sections rolled; for the working of the steel greatly affects the physical properties of the finished bar, thick metal giving different results from thin.

"It is the Inspector's duty to know that tests for the material are cut from sections of the same heat that they represent. All finished material should be stamped with the heat number of the steel from which it is made; and when the material is cut up, these numbers should be reproduced on the shorter lengths. The heat from which a piece is made can then be identified at any time.

"5. *Making Physical Tests.*

"The Inspector should see that the test pieces are properly prepared and of the size required.

"*a*. Tensile Tests: In test for ultimate strength and elastic limit, the Inspector should satisfy himself that the machine is correct and that it is properly operated. He should check the dimensions for the determination of elongation and contraction, and should always observe the fracture. In case a test piece should fail on account of a local defect, or on account of breaking in the grips of the testing machine, a retest should be allowed.

"*b*. Bending Test (Cold): The bending of test pieces can be performed in the way most convenient to the Manufacturer, but they must be flattened down to the amount required in the specifications.

"*c*. Bending Tests (Quench): In the case of quench-tests, the Inspector should see that the specimens are heated properly and that the water for quenching is of the specified temperature. The intention of this test is to show whether the steel, in case it should be heated to a red heat and suddenly cooled, would become so brittle as to render it unsafe. In some cases this test tends to water-anneal the steel; but, as a rule, it hardens it. If this test be conducted improperly, the steel will be either annealed or rendered worthless.

"*d*. Hot Tests: In the case of hot tests the Inspector must see that the metal is at the specified temperature while being bent or hammered.

"*e*. Drift Tests: In making drift tests, the hole should be punched at the specified distance from the edge of the piece to be tested, and a drift pin of proper taper should be used.

"*f*. Special Tests: Other tests, sometimes required, such as opening and closing tests, flattening tests, breaking tests, torsional tests, impact tests, fracture tests, etc., must be made in strict accordance with the specifications.

"6. *Chemical Tests.*

"The mill should supply the Inspector with a full chemical analysis of each heat, which he is at liberty to check at any time by making his own analysis. In case check analyses are taken, the Manufacturer should be allowed to make analyses from the same drillings as used by the Inspector. When the specifications require chemical analyses of the finished material, the drillings for these analyses should be made, in the presence of the Inspector, from one end of the fractured tensile test piece, and the Manufacturer should be allowed to make analyses from the same drillings.

"7. *Report of Tests.*

"After all the material for an order is rolled and tested, the report of tests should be made in such a form that it can be easily referred to, and so that the material used in any part of the structure may be identified.

"8. *Surface Inspection.*

"The amount of inspection given in the mill is controlled to a great extent by the specifications. Some specifications require the watching of the steel from the time the raw material is put into the reducing furnace until it gets its final shape, and that after it is rolled to its final shape each bar is to be turned and examined and the heat number identified. For the turning of material all mills have combined on charging $2 extra a ton.

"If each individual piece is not examined, each section should be inspected, to see if it has been rolled true and to gauge, that all fillets are well formed, that the web is smooth and free from buckles, and that there are no lumps or unevennesses (due to defective rolls) which will interfere with the assembling. This inspection insures the section being good, and that individual defective bars will be seen and rejected during the shop inspection. In case bad bars are seen while inspecting material in lots, they should be thrown out at once; and if there are many bad bars, either all the material should be rejected or each individual piece should be turned and inspected.

"9. *Inspector's Note-Book.*

"At the top of the page put the name of the structure, and under this the order number or any other numbers that may be useful for reference. Then write an abstract of the specifications. Leave the remainder of the page and the next page blank for any special remarks or modifications of the specifications. On the following pages make a classified list of material required; the different sections being placed in a column on the left side of the page, with the remainder of the page to the right blank for inserting progress data, such as: Scheduled time for rolling, date of tests, heat numbers, etc. When all the material of a required section is rolled, run a pencil line through the item.

"The advantage of a well kept and simply arranged note-book is to add system to the work of inspecting, and to enable the Inspector, at any time, to know the exact condition of the work in the mill.

"10. *Checking and Recording Shipments.*

"When material is shipped from the mill, the Inspector is to check the shipments and is to receive copies of the shipping bills, containing sections, weights, lengths, and

heat numbers. After assuring himself that these bills are correct, the Inspector is to check off on the order sheets the material shipped, and is to put on them the heat numbers and date of shipment, and then is to compare the actual weights with the estimated weights in order to see that the material is rolled within the allowable weight limits. By referring to the order sheets at any time the Inspector can determine what has been shipped and what is still due on the order; and when the order is completed, he has a full account of the heats used and the amount of material in each heat.

"11. *The Inspector should not allow any material to be shipped until after it is tested.*

"12. *Reports.*

"Reports of mill work must be made at the end of each week and should state:
Total estimated weight of material on order.
Total estimated weight of material rolled or shipped.
Total actual weight of material rolled or shipped.
Sections rolled and tested and weight shipped during the week.
What sections are expected to be rolled during the following week.
Remarks....................

"In cases where engineers want reports in different forms, the character of the reports must be changed as required.

"SHOP WORK

"1. *Study of Blue Prints.*

"Before the shop work commences the Inspector must be provided with a set of prints, approved by the Engineer in charge of the work. On the receipt of these, he must first study the general plans and obtain a clear idea of the structure in its entirety. He must then study carefully all points and details in connection with the specifications and see that all notes on prints agree therewith; for these notes are the instructions to the shop as to how the work shall be done. He should make a memorandum, to be submitted to the Engineer, of all points of disagreement between drawings and specifications. He should also, in studying over the details, make notes on the prints of any points where difficulties in construction are liable to arise, and of such details as must be absolutely correct, and should devise methods of checking and insuring their accuracy. In cases where standard connections are not used (in beam and angle work), he should make a mark on the print to emphasize that fact. Where sections are given in pounds per foot, he should put on the print the thickness, so that he can check up the said sections during inspection. He should note on the prints the clearances allowed so as to be sure that the work will go together properly.

"2. *Preparing Material for Shop Work and Laying out Work.*

"All sections should be straight before any work is laid out to template. The templates should be made of at least ½" plank; and in cases where a template is built up, the different parts should be securely fastened together, so that there is no chance of its getting out of shape. When a member is being laid out, the templates must be in true alignment and firmly clamped to it. The center punch should fit the holes in the template snugly; and it should be hit with sufficient force to make a well defined centre mark. When the template is removed, all centre marks should be marked with white lead, and the location marks should be put on the member.

"3. *Punching.*

"The difference in size between the die and the punch should not exceed the following limit: $^{1}/_{16}''$ for punching metal up to ½" thick, and $^{3}/_{32}''$ for thicker metal. The punch and die should be well formed and smooth, and the punched holes should be free from jagged edges and excessive burring.

[illegible] Inspector [illegible] any [illegible] by the way it punches, and can also determine [illegible]. Any sections that have been bent by [illegible] beam to roughness of the section [illegible]

[illegible] the Inspector must see that abutting surfaces [illegible], and that they are well painted with the specified [illegible] that will be inaccessible after assembling are properly [illegible] bear in mind that this is the only protection these surfaces [illegible] the proper painting of them is of more importance than [illegible] can be recleaned and painted when desired.

[illegible] all the work of assembling, and should see that proper [illegible] to insure connections being properly located and adjusted [illegible] and before any riveting is done, he should see that all [illegible] tightly together, that the holes match well, and that they [illegible] there will be no shifting of the work by the use of drift pins. [illegible] reamer should be kept perpendicular to the face of the metal [illegible] abutting members should be so tightly bolted together that [illegible] between them by the reamer. In the case of machined surfaces [illegible], the Inspector should see that the work is drawn up [illegible] of the bearing is obtained. Before any riveting is done, [illegible] as much as possible.

[illegible]

[illegible] more than $^1/_{16}''$ less in diameter than the diameter of [illegible] should be of the proper lengths. They should be properly [illegible] they are allowed to cool. When the metal to be riveted is [illegible] with the riveting. The head end of the rivet should [illegible] plain end, so as to cause the head end to upset before the [illegible] to be formed, and thus fill the hole completely. On account [illegible] all around the rivet, which causes the latter to cool rapidly, [illegible] as it is put in place and before it has time to cool. The [illegible] the rivet until it is sufficiently cold to take a set.

[illegible] see that the riveter is properly operated, and that power- [illegible] possible. He should constantly test the rivets so as [illegible]. Where rivets have to be driven by hand, he should test [illegible] see that the riveting is well done in all difficult places. [illegible] that the work is not being drawn out of shape, nor twisted, [illegible] being shifted.

[illegible] formed and in good alignment; and where work is ex- [illegible] to have the rivets make a good appearance in every

[illegible]

[illegible] facing is done wherever called for. He should [illegible] for facing will give accurate results, and should [illegible] faced, so as to see that it is laid out properly. In

cases where surfaces are faced on a bevel, the bed of the facer is the best place to check the accuracy of the work.

"Where built up sections are faced, all component parts should be securely riveted or bolted together, as near as possible to the finished surface. In other words, the facing tools should cut through all the component parts as though they were a solid piece of metal.

"7. *Checking Metal.*

"All through the shop inspection, the Inspector should have with him his note book on mill inspection, and should check up the heat numbers, in order to assure himself that the steel he tested is being used. In case he did not inspect the steel himself in the mill, a list of the heats tested and accepted will be supplied him by the inspector who attended to the mill work. He should also check up the different sections by calipering and measuring them.

"8. *Weighing.*

"When the work is finished in the shop it should be weighed, and the Inspector should check these weights.

"9. *Cleaning and Painting.*

"All steelwork must be well cleaned of scale, rust, dirt, and shop grease, and painted with the specified paint. The paint must be well rubbed in, and all cracks and open places must be filled. The Inspector must have quick methods of determining the character of the paint used, and must make what analyses he considers necessary to determine its quality. The knowledge of paints is a study in itself, and special information and instructions concerning the specified paint will be given to the Inspector.

"10. *Final Checking up and Measuring of Work.*

"The Inspector should make a final inspection of the work, and assure himself that all dimensions are correct, and that the work will go together without trouble. In case where it is very complicated, it should be assembled at the shop, the necessary reaming and chipping done, and the different members match-marked.

"Among other things specially to observe and check are: The distance from last hole to end of member, chipping of the countersunk rivets, smoothness of bearing surfaces where steelwork is to bear on masonry, and the proper finishing and smoothing up of slotted holes.

"11. *Shipping.*

"As material is shipped, it should be checked off on the plans; and the Inspector should see that it is forwarded in such a manner as not to delay the erection in the field. Often the omission to ship an important member will completely block the work of erection for a considerable time.

"12. *Conclusion.*

"Always have your work well in hand; be observant; and if you have any fault to find with the way the work is being done, speak of it to the right parties, and have the required remedy in the proper way.

"Be courteous but firm, and always mindful of your duty. Do not expect perfect work, but do everything in your power to obtain the best results and to make the work a credit to all concerned; and remember that it is better to be respected for conscientious work than to cater for friendships at the expense of your own reputation.

"Work with a view of increasing your own knowledge and gaining in expertness. Make notes of what you observe and of all experiences gained on each piece of work.

"Add to these instructions any points you think will strengthen them, for they are intended as a foundation for the attainment of the best results."

& Co.'s general and detailed

INFORMATION TO INSPECTORS

with a standard steel tape and our special stamping
responsible. You will supply yourself with light
edge, calipers, rule, and other necessary tools.

with a full line of our blanks, and you should see that they

be made weekly, or according to special instructions;
check of contractor's estimates, as per special instructions, final
Press or carbon copies of letters and carbon copies of
diary of each day's inspection should be kept for purposes
All reports should be neatly made out with copying pencil
press copy and forward original to our clients. Where more
make extra carbon copies.

INSPECTION OF MATERIAL

as regards stock used and methods of piling, or casting,
with melt numbers, preparing test pieces, weighing, etc.
known to represent material inspected.

be made before surface inspection; must in all cases be
and bending tests are as important as tensile tests.
outlining on regular form. Punching, forging, and other
instructions.

and accuracy frequently investigated. Where inde-
samples must be taken personally.

for surface defects, section, and straightness as
completely inspected and acceptable, identified by our
stamped. Universal mill plates should receive special
straight, must be tried with a 'line.' Do not allow
inch in 30 ft. Section should be checked with rule and
suspicion of light weight, pieces should be weighed. Lists
should be made on 'Material Represented' blanks.
the time with shipping clerk's list and later with
proper facilities for inspection during daylight; if such
the best inspection possible and report the facts.

blanks, and send us copies of shipping invoices. In
inspection, or of rejected material, advise us at once,

giving date and car number so that we may make proper arrangements for inspection on receipt at shops. On completion of each order return order sheets to us checked off showing that each piece has been accounted for by melt number.

"6. *General.*

"In the interest of clients and of the bridge shops, you should make special efforts to facilitate rolling and shipping, and should see that rolling for items for your orders is completed before rolls are changed and that other orders are not allowed preference. Give special attention to following up odd items in list, or arising from condemnation. Advise us promptly of any unreasonable delays.

"GENERAL INSTRUCTIONS TO SHOP INSPECTORS

"1. Check the shop drawings for clearances, and estimate the weights, when so instructed, in advance of manufacture, reporting results to us before shipment begins; see that every dimension which in any way affects the assembling of the work at the site is correct; that all clearances are ample and that the drawings which you are using have been approved.

"2. Prior to actual inspection, you should carefully compare your tape with the shop standard, note the differences, if any, at each even five feet, and thereafter make the proper allowances for all measurements.

"3. You are to keep in close communication with us, not only through report forms, but also should consult us frequently regarding the standing of shops, shop methods, and all important questions arising in connection with the work. Inasmuch as our inspection contemplates considerable of our personal supervision, you should advise as to the proper time to go over the work with you and later to see the work at its most important stages. This is particularly intended to apply to important riveted and skew spans, draw spans, and turntables.

"4. Whereas your authority does not extend over shop methods, good inspection requires the prevention rather than the mere discovery of defective workmanship, and it must be conducted with judgment to anticipate poor work. It is also your duty, second only to that to our clients, to save contractors all reasonable expense or delay; and you must conform to their right to prompt attention and your presence during working hours. In the interests of all parties concerned, it is necessary that you give the work constant supervision and conduct the inspection with foresight and tact.

"INSPECTION DURING MANUFACTURE

"You should read carefully all specifications as soon as received and make note of important requirements. Do not assume that all specifications are alike and that general shop methods are acceptable. You should keep a close watch on all details of manufacture, giving particular attention to the following points:

"1. You should begin work with the template and pattern shops, particularly on drawbridge, skew span, or lattice girder inspection, and should check templates and patterns as far as possible, and without fail witness all laying out of full sized templates.

"2. Careful surface inspection of all material during handling, punching, and assembling to discover defects not found at the mills.

"3. Watch straightness of material, particularly heavy angles after punching.

"4. Supervise all punching closely; give special attention to accuracy of punching and use of proper dies and punches; have special care for cracks developed by punching; and watch for evidence of burnt or over-heated steel, condemning such rigidly. It is only at punching that slotted holes can be prevented. Punching must be accurate or the material must be rejected.

"5. Care at assembling: Matching of holes and use of sufficient number of bolts; proper reaming; straightness of assembled members; removal of all burrs; bearing of

[illegible]

effect in improving the
the yard. See that defective
marked.

FINISHED MEMBERS

members should be made as soon as they leave the
applied; the following points should receive your

over for defective material or defects caused in
lattice or angle bars split), also for bearing of

tested and examined for split or wasted heads and

of all pin holes; whether in axis of member or as called
axis.
of pins and rollers,—examine for flaws.
measurements, centre to centre, faced end to faced end, and out
and girders.
members, check carefully to be sure that material is of
as required.
where pieces are likely to interfere in the field,
of chord sections and posts, thickness of heads of eye-
chords and posts, depth of stringers and floor-beams, etc.
are at right angles to axis of member, or are inclined
are beveled. Floor connections not faced off too much,

of countersunk and flat head rivets.
and location of all bolt and field rivet holes, pin holes,

This is very important through the ease and frequency
are made and overlooked.
corresponding field connections (*e. g.*, floor system); get a
for this purpose when desirable on account of a large

particular attention. All eye-bars of a kind should
of pin holes, although each kind of bar may vary from
$^1/_{32}$″. In addition to length and pin-hole measure-
be calipered and measured; and bars, particularly
utmost care for flaws and piping. No flaws whatever

chords should be lined up with splice plates in
riveted trusses, skew spans, skew portals, or other
be assembled. Connections of all work assembled

be adequate and should be checked.
done before fitting up and on finished work. See
See that all material is free from scale or rust,
and dry.

"17. Weighing should be known to be correct, and shipment should be watched to see that pieces not accepted are not shipped; also that loading is properly done to prevent injury during transportation. Compare actual and estimated weights before shipments leave the works and determine the reason for any difference. Pieces of different kinds must be weighed separately.

"18. Immediately shipments are made report to us. Keep memorandum of pieces and weights. When final shipment is made compare your total for actual weight with that of the shop to see that you have all invoices and advise us, sending invoices and your estimate of weights and final report.

"SHOP INSPECTORS' FINAL REPORT

Plans

"*Description:* As soon as plans are received report a description of work, type of structure, pin-connected, riveted or plate girder, deck, half through or through, single or double track (if highway, width), length c. to c. and clear; note if skewed.

Material

"As soon as plans are received we must have a list of all members, arranged in same order as estimated weights. This can be taken from the plans or generally had from the drawing room for the asking.

Weights

"*As soon as plans of bridges are received* weights must be estimated and shown for different members, grouped into:

" (1) Trusses, (2) Girders, (3) Floor, (4) Wind Bracing, (5) Pier Members, (6) Field Rivets and Miscellaneous, (7) Draw Machinery (need not be estimated unless under special instructions). This can be done when list of material is made out, and should follow same order.

"Scale weights must be compared with estimated weights, and weighing must be done accurately, so that such comparison can be made. If several pieces are to be weighed together, the total must be reasonably proportioned according to estimated weights and must so check. This must not be permitted for important pieces. At completion of job, compare your total weight with that of the shop and be sure you have all invoices.

"*Answer Every Question Below Within One Day of Final Shipment. When Desirable State Fully in Detail*

"1. What errors did you find in plans? How corrected?

"2. Did you examine all material and compare with detail plans for size and section during shop inspection; did you condemn any and why?

"3. Were any errors due to incorrect templates? What and how corrected?

"4. Was material straight or straightened before and after punching?

"5. Did any material crack in manufacture, and was it replaced?

"6. How accurate was punching? Did you do anything to watch and improve punching?

"7. What was the size of dies and punches? Full size or sub-punched?

"8. Were assembled members straight and held tight with sufficient bolts? Did holes match reasonably?

"9. Was reaming done? With what kind of tool? How much metal was removed? Were all the holes cleaned out? Were burrs removed? Were finished holes slotted, and to what extent?

[illegible] at assembling and did you find any [illegible]
[illegible]? Where were they located, and what [illegible]

[illegible] in machine work? (Pin holes, faced ends, etc.)
[illegible] reamed to iron template, and what?
[illegible] assembled and reamed? Were they [illegible]

[illegible] Were centre and machinery assembled? How much of [illegible]
[illegible] What did you find? (State this in detail.) Were [illegible]

[illegible] was used? How many coats were used at assembling
[illegible] clean and dry? How was cleaning done? Was painting
[illegible] before shipment? Was the finish good or streaky?
[illegible] examinations? Was every section of material as called
[illegible]? Were members straight? Was general appearance neat

[illegible] correct? Did you personally witness weighing?
[illegible] and packing done? Were bolts and rivets boxed? Were

[illegible] shop work began; also date when final shipment was made."

[illegible] extracts from a letter of Messrs. Robert W. Hunt
[illegible] 1915:

[illegible] over Chapter 21 of *De Pontibus* on 'Inspection of Materials
[illegible] believe that your standard instructions to the Inspecting
[illegible] employed to look after work at mills and shops pretty
[illegible] features to be looked after.
[illegible] that all inspectors employed on work of this character
[illegible] knowledge, and common sense, to see that the requirements
[illegible] are complied with, without going into minute detailed
[illegible] reading over these paragraphs in *De Pontibus*, a number
[illegible] not included therein, suggest themselves, and which are
[illegible] some inspectors, as follows:

[illegible] conditions at the shop and endeavor to expedite the work
[illegible] shipped from the mill in the order in which it is needed

[illegible] stamping of test specimens and verify the heat numbers
[illegible] records of mill analysis promptly and check against
[illegible] accepting the material.
[illegible] surface defects, evidence of excessive gagging, or injury
[illegible] look out for buckles in wide plates and the alignment
[illegible] material for section and weight, and do not leave these
[illegible] or shipping clerk.
[illegible] tensile, bending, and drifting tests; check the measure-
[illegible] that the testing machine is properly manipulated and
[illegible] is not exceeded. Check the readings on the machine,
[illegible] under test and the character of the fracture. Do
[illegible] the mill's record of tests.

[illegible] specifications and of the conditions of the contract,
[illegible] customer's actual need of the work, desired order of
[illegible] to which particular attention should be paid.

[illegible] with the output, so that errors or defects may be [illegible] the shop, thereby avoiding [illegible] the field connections, paying particular attention [illegible] drawings, and report promptly any interference which may [illegible] that the correct sizes of punches and dies are used, [illegible] that the proper amount of metal is left to be removed [illegible]

"See that all reamed holes are true, cylindrical, and not [illegible] removed from the holes, and that no chips or [illegible] between the contact parts.

"See that plenty of bolts are used in assembling so as to [illegible] tight and that sufficient pressure of air is maintained constantly [illegible] compact the material, completely filling the holes and producing [illegible] the rivet heads are of uniform size and well lined up.

"Make sure that reaming-templets are properly set and [illegible]

"See that all splices are properly fitted, and that milled surfaces [illegible] are in close contact during reaming and riveting.

"See that proper camber blocking is used in assembling girders [illegible] obtain the desired amount of camber before reaming.

"Make sure that all spliced members are plainly match-[illegible] marking diagram for all work which has been assembled and [illegible]

"Check carefully sizes of pins and pin holes, and be sure that [illegible] bored at right angles to the axis of the member.

"Look out for twists, bends, and kinks in the finished [illegible] that when leaving the shop they are in proper condition.

"Verify the erection marks and see that they are legible and [illegible] spicuous place.

"See that the weights of all main members, especially girders [illegible] sections, are plainly marked on the piece for the erector's benefit.

"See that all large members, particularly girders and chord sections [illegible] as to be headed in the right direction on arrival at the site.

"Make sure that all loose pieces are bolted in place for shipment, [illegible] ings, and that other small parts are properly boxed or otherwise [illegible] in transit.

"See that material is loaded in accordance with instructions and [illegible] order for erection.

"Examine cars on which material is loaded and see that they [illegible] before being sent out.

"In case of any dispute between inspectors and the manufacturer [illegible] from the plans and specifications, the work in question should be [illegible] immediately reported to the Engineers.

"All drawing room errors, as well as shop errors which affect field [illegible] also be recorded and reported immediately.

"*General.*

"Inspection Bureau should employ only first-class men for [illegible] experience and training in the particular line of work on which [illegible] should not borrow or hire the bridge company's or mill's [illegible] inspectors when assistance is needed."

[illegible] its duties are only [illegible] manufacture of the material in the [illegible] more directly to the [illegible] they are of such excellence that [illegible] not hereinbefore fully treated are reproduced [illegible]

[illegible] should make sure that the testing machine [illegible] specified speed of pulling (usually 2 inches per minute) [illegible] and thereafter increased to 6 inches per minute.

[illegible] *of Dimensions.*—When practicable all material [illegible] before shipment, such inspection to cover surface [illegible] conditions at mills be such as to prevent inspection being [illegible] be subject to inspection at point of destination, with the [illegible] material defective as regards dimensions, finish, or surface [illegible] to rejection and replacement at the maker's expense.

[illegible] Inspector should be on hand whenever material is un- [illegible] check the material with the shipping invoice, so that [illegible] received as has been tested and accepted by the inspector [illegible]

[illegible] Material received from mills and held at shops awaiting [illegible] from rust; oiling of the tops, sides, and ends of piles [illegible]

[illegible] 'merchantably straight' when shipped from mills, [illegible] some cases angles and shapes, require further straightening [illegible] straightening should be done in rolls and not by sledges or [illegible] be removed by adjusting the rolls or placing narrow strips [illegible] or stretching the outer edges when passing through [illegible] surfaces will increase the defect.

[illegible] portion only of a plate, angle, or shape is heated for the pur- [illegible] strict compliance with the specifications requires that [illegible] This requirement is at times disregarded, as in the case [illegible] through plate girders where, owing to the fact that metal at [illegible] annealing may be waived without risk. Such plates [illegible] be bent to a true curve and be free from short bends or [illegible] of angles will bear evenly on the plate.

[illegible]—In girders which have a greater depth at the centre [illegible] girders of turntables, long floor-beams, etc., the flange [illegible] are generally given two decided bends, requiring partial [illegible]. As such angles usually occur in girders which [illegible] and impact, they should be annealed, as called for in all [illegible] to the lack of facilities for annealing in most bridge shops, [illegible]. (The proper course for the Inspector to pursue [illegible] accept the work on his own responsibility, but to take [illegible] and the shop manager, and let his employer decide [illegible] the annealing, as an excess of strength may have been [illegible] for the possible defects in the unannealed angles.)

[illegible]—Material which has curved during the process of [illegible]

[illegible] *Work.*—Sub-punched and reamed work should,

[illegible] be so thoroughly bolted
[illegible] avoid the accumulation of reamer
[illegible] solid the various parts should be held
[illegible] and by a sufficient number of clamps to
being drilled. (High speed steel has made it possible
lubricants, except for an occasional oiling of the drill
[illegible] holes.)

"*Bolting Members Against Distortion During Dri*
forming a member have been assembled, the entire member,
or girder, should be free from twist, wind, or bend, and should
[illegible] against twist or change of form prior to or during

"*Injury to Material in Handling.*—In handling heavy
that edges of plates or angles are not scored or bent by chains
(The use of blocking will prevent this.)

"*Driving Rivets in Long Compression Members.*—In riveting
long compression members, it is well to drive at different
continuous line. A twist or curve can be avoided by driving
flange and returning over the work to drive rivets in omitted
assembling bolts have been removed.

"*Countersunk Rivets.*—In driving countersunk rivets the
one that will completely fill the countersink without
the excess should be as small as possible in order to avoid
loosen rivets, particularly in thin material.

"*Driving Rivets.*—All rivets are intended and expected to be
symmetrical heads and to be in true alignment. Loose rivets
if material is carefully straightened and thoroughly bolted in
lengths of rivets are used, and if the machines employed are of
the above precautions have been observed the number of loose
be small, but when these precautions have been neglected a
rivets is likely to be found, and, therefore, special care should be
rivets.

"*Testing of Rivets.*—The proper testing of rivets requires
Specifications call for all rivets to be tight, and good practice
be no loose rivets in any part of a structure. However, as the
be measured with instruments of precision, but can only be
depending upon the keenness of the Inspector's ear to
ability to feel the vibrations when the rivets are struck by a hammer,
like others depending upon the testimony of the senses, are not
may be pronounced as tight by one inspector and as doubtful by
fore, of the greatest importance that the testing of rivets should
functory manner, but that intelligence and judgment should be
of the Inspector as to the functions which the rivets have to

"*Important Rivets.*—In cases where the whole strength of a
depends upon the resistance of the rivets, the utmost care should
and only such rivets allowed as are considered absolutely tight.
plate girders, those connecting reinforcing plates to main
and those in riveted connections of either tension or
strength of the connection depends solely upon the value of the
bearing value of the abutting surfaces, may be mentioned as
absolutely tight. In rivets which receive no calculated
which is simply to clamp the material together (such as
members in alignment (such as rivets in lattice bars or tie
absolute tightness is not imperative.

"*Alignment of Rivets.*—The shape and alignment of

[illegible] should be made in this [illegible] which while upsetting is not confined to any [illegible] in a straight line or in the shape of bends [illegible]

[illegible] The advisability of replacing loose rivets will depend on [illegible] of securing better results by cutting them out and [illegible] injury to the material or adjacent rivets. The motive [illegible] for the improvement of the work and not the imposing of a [illegible]

[illegible] in close proximity are loose, they should be removed [illegible] loosened by reason of such removal, and, after clamping [illegible] together, the entire lot should be redriven. Rivets to be [illegible] be drilled out instead of being backed out with a punch, [illegible] through several thicknesses of metal.

[illegible]—The milling to length or bearing is a matter deserving [illegible] the pieces to be milled should be supported on a temporary [illegible] which is milled away during the operation. Where this is [illegible] taken should be light to avoid the breaking away or tearing of [illegible] side of cut. Cutters having broken cutting edges productive [illegible] be removed and replaced, and the speed of feed should be [illegible] smooth and even finished surface.

[illegible]—In milling the ends of stringers or similar members [illegible] angles project and constitute the length over all, care [illegible] angles square and flush with each other before being [illegible] of such angles will be reduced unevenly during the [illegible] places to less than the thickness required.

[illegible]—Chamfering of ends of stiffener angles should conform to [illegible] they are to be fitted and not be simply rough ground or [illegible]—Chamfering of plates used for reinforcing webs of beams [illegible] bolsters should be accurately done by planing with a tool [illegible] of the beam or channel to which they are to connect.

[illegible] I-Beams and Channels.—The faces of flanges of beams or [illegible] should be planed to a right angle with centre of web [illegible] imbedded and covered with concrete). Flanges of these [illegible] rolls "out of square" with webs, and planing is essential [illegible] or end shoes.

[illegible]—Web plates of girders should be free from buckles, but [illegible] discovered until riveting has been completed may be [illegible] of buckle does not exceed ½″ in 60″. (This is an old [illegible] effective straightening machines is seldom resorted to.)

[illegible] Columns.—Base or cap plates of columns, if not planed, [illegible] so as to ensure a bearing of the entire section of shaft [illegible] plates and bearing plates at ends of girders or stringers [illegible] after riveting, and any curving or deviation from [illegible] by restraightening.

[illegible] During Manufacture.—Piping or other interior or [illegible], etc., occasionally develop during the various proc- [illegible] containing such defects should, under ordinary [illegible]. The location of the defect, its extent, the neces- [illegible] and the consequence of delay should, however, be taken [illegible] conditions it may be possible to make use of [illegible] safeguarding the strength of the member without [illegible]

[illegible]—Bolts to be used in permanent drilled or reamed

[illegible] imperfections, but [illegible] unimportant and those which render the [illegible] be checked as to size and dimensions. [illegible] inspector should ascertain that they have been [illegible] indicated by their color, which should be [illegible] If minor defects should be discovered in steel [illegible], the correction of such minor defects by [illegible]

"*Reaming Field Connections to Templates.*—The reaming [illegible] those of floor-beams to posts and stringers to floor-beams, [illegible] templates. These templates should be checked with the [illegible]. For this purpose the drawings of posts as well as floor-[illegible] floor-beam to post connections, and for stringer to floor-beam [illegible] for both stringers and floor-beams should be used.

"*Checking Connecting Angles at Ends of Floor-beams and* [illegible] connecting angles at ends of floor-beams or stringers are not reversible, [illegible] to see that angles are correctly placed, giving the proper starting [illegible] to first hole. Stringers are frequently alike top and bottom, with [illegible] for lateral connections or floor bolts; and it is possible, and [illegible] end connection angles are reversed and riveted with top and [illegible] member.

"*Assembling and Reaming Riveted Trusses.*—When riveted [illegible] complete with all truss members and connections in place, such [illegible] trusses by lying flat and not in a vertical position. It is then [illegible] avoid the turning of entire truss, to use long shanked reamers [illegible] on both sides of chord without changing position of truss.

"*Camber in Riveted Trusses.*—When trusses are assembled [illegible] of the web members should be checked to make sure that they [illegible] camber; but, before reaming, this camber should be checked, [illegible] to some extent by drifting the sub-punched holes, after which [illegible] firmly bolted to hold bearing joints in close contact. Fillers [illegible] are to be shipped in place, without removal after reaming, should [illegible] of paint the same as other surfaces in contact, otherwise they [illegible] be riveted in place at site without having been painted.

"*Reaming Field Connections in Riveted Trusses to Templates.*—[illegible] large to permit of complete assembling, it becomes necessary [illegible] reaming the holes of each connection (other than chord or end [illegible] should be reamed while joints are abutting and in line.) Such [illegible] provided with centre lines and marks indicating position as [illegible] centre of holes in member being reamed to centre line of member to [illegible] They should be either of metal or of seasoned wood with metal [illegible] templates are to be preferred if they are to be used on duplicate [illegible]

"*Checking Sizes of Pins.*—In pins of smaller sizes, say up to [illegible] properly be checked by ring or snap gauge furnished by the shop. [illegible] the circumference should be measured with a tape in addition to [illegible] calipers.

"*Checking Pin Holes.*—Pin holes of moderate size can be [illegible] usually to be found at shops, but when such gauges are not [illegible] diameter pin holes, the diameter should be carefully checked [illegible] As the clearance for pins seldom exceeds $^{1}/_{32}$″, it is important [illegible]

[illegible]

[illegible] of the diameter of the rollers [illegible] this motion is controlled by stops or [illegible] should, wherever practicable, be [illegible] the thickness and pins passed through [illegible] and uniformity and correctness of length of [illegible] should also be examined singly as to gauge of [illegible]. The diameter of heads of bars should be [illegible] plates of end posts or chords and chipped if necessary [illegible]

[illegible] bars connected by turnbuckles should, when coupled, [illegible] of the length shown on shop print. Threads of [illegible] and capable of entering the turnbuckle to the full length [illegible] wrench having a leverage of four feet. With loose fitting [illegible] provided with jam nuts, are liable to work loose in service.

[illegible] Parts of Movable Bridges

[illegible] parts of movable bridges requires special care, and [illegible] to experienced men only.

[illegible] carefully study the design of all the details and discriminate [illegible] which must be exact and those in which slight variations [illegible]

[illegible] and finish should be equal to that of the best practice [illegible] the parts of the operating machinery of movable bridges [illegible] weather, the finish should be confined to the bearing [illegible] and wherever it is required to secure precise and accurate [illegible]

[illegible]—As it is of the greatest importance to have all fixed [illegible] movable bridges properly fastened so that they may not become [illegible] of the bridge, special care should be exercised to assure [illegible] as bearings for shafts or journals, hubs of wheels, pulleys, [illegible] parts to the shafts or axles to which they are attached. [illegible] used to hold such parts in place should have a tight fit [illegible] precautions are provided for in the design, and all nuts [illegible]

[illegible] pulleys, couplings, etc., should, besides having a close [illegible] which they are attached, be provided with properly fitting [illegible] should be paid to the fitting of such keys. If a hub performs [illegible] end next to the bearing should be faced. Holes in hubs [illegible] be bored concentric with pitch circle.

[illegible] should satisfy himself that the proper material as called [illegible] for discs, friction rollers, or balls used in pivots. He [illegible] accurately turned and finished to gauge and oil tempered, [illegible] after hardening they are accurately ground to their final [illegible] discs should have their sliding surfaces finished to a [illegible]

[illegible] worms should be cut, and the teeth of worm wheels [illegible]

[illegible] should see that provision is made for proper lubri-

[illegible] of all rotating and sliding surfaces and [illegible]

"*Assembling Turntable Centres.*—Turntable centres [illegible] roller or disc type, should be assembled and made [illegible] to develop existence of soft or weak spots in roller [illegible] holes and grooves should be provided, whether specifi[illegible] their presence is apparent.

"*Assembling Turntables for Swing Bridges.*—Track, [illegible] turntables for swing bridges, together with circular, radial, [illegible] and other parts belonging to and connecting to the turntable [illegible] assembled. After assembling, all parts of the operating [illegible] positions and attachments, should, as far as possible, be tried in [illegible]

"*Proprietary Paints.*—Where proprietary paints are called for [illegible] the inspector should see that the original packages from which [illegible] bear the brand, trademark, or other identification mark of the [illegible] adulteration or dilution of such paints should be permitted, [illegible] and recommended by the manufacturer.

"*Red Oxide of Lead Paint.*—Where 'Red Oxide of Lead' is specified [illegible] and linseed oil as the vehicle, it is essential that both lead and oil be [illegible] so far as to establish that the quality of such materials is as claimed [illegible] whose names appear on the original packages.

"Red lead or other paints containing heavy pigments are difficult [illegible] owing to the tendency of the pigments to precipitate or settle, [illegible] accumulations of excess pigment and separation from the oil or [illegible] prevented by the use of lamp black if permitted by the specifications [illegible] permissible, the use of a small amount (say 1 gill per gallon) of [illegible] an immediate partial hardening, thus preventing this objectionable [illegible] streaking.

"*Records for Erection.*—A record should be kept of all matters [illegible] at site, as, for instance, the changing of rivets from shop to field [illegible] marking of parts made non-interchangeable by reason of [illegible] possibility of close-fitting connections, and the match-marking of [illegible] of which record should be forwarded to the erector."

Some two decades ago the author had made for him [illegible] inspectors a rather interesting series of tests to determine [illegible] accuracy of sub-punched rivet-holes. These tests were [illegible] metal was assembled for reaming by inserting rods of [illegible] in the assembled holes. From the results thereof the [illegible] the following clause for his specifications; and he has [illegible] It is Clause No. 83 of Chapter LXXIX.

"All punched work shall be so accurately done that, after the [illegible] pieces are assembled and before the reaming is commenced, forty [illegible] holes can be entered easily by a rod of one-sixteenth ($^1/_{16}$) of an [illegible] that of the punched holes, eighty (80) per cent by a rod of a di[illegible] of an inch less than same, and one hundred (100) per cent by a [illegible] quarter (¼) of an inch less than same. Any shopwork not com[illegible] ment will be subject to rejection by the Inspector."

It will be noticed that this specification does n[illegible] work that does not come up to its exact requirem[illegible]

[illegible] between simple and [illegible] unimportant connections, and the [illegible] component pieces.

[illegible] inspectors previously suggested were established, [illegible] for the engineering profession by laying out a series [illegible] members and details of bridges and other structural [illegible] from time to time as a portion of the inspection [illegible]. This would need the assistance of the consulting [illegible] preparing their specifications, should include, as a part [illegible] manufacturers, the making, under the supervision of [illegible] certain tests of full size parts, it being understood [illegible] results of such tests shall be of direct value to the [illegible] the work covered by the specifications. The author [illegible] been endeavoring in this way to obtain some much-[illegible] concerning the strength of both main members and [illegible] and elevated railroads; but his attempts to have the [illegible] always proved successful.

[illegible] occurs in a bridge engineer's practice that he is ab-[illegible] using stock material for a structure. Such a method [illegible] structural steelwork is always highly objectionable [illegible] serious a matter today as it used to be, because the [illegible] of rolled metal has become materially improved [illegible] systematized); nevertheless there are occasions when a [illegible] built upon the spur of the moment in order to meet [illegible] will not permit of the metal being rolled specially. [illegible] engineer has to make the best of a bad business; and, [illegible] will be liberal in proportioning his sections (unless the [illegible] from stock); and he should give the metal that he [illegible] investigation as possible. The method adopted by [illegible] Co. is given as follows:

[illegible] or Consideration of Stock Material

[illegible] of dealing with the question of use of stock material at [illegible] be followed closely:

[illegible] for the use of stock material is given by our client and it [illegible] question of tests or the identifying of metal is waived, we [illegible] the material for size, section, and surface.

[illegible] for the use of stock material is given by client under the [illegible] be identified by us, we must make the attempt to make [illegible] requesting the shop to furnish us with record tests giving [illegible] these are available, a further endeavor must be made to [illegible] the material. This will generally be found to be im-[illegible] are retained on the material cut into commercial [illegible] in the shop stock supply. If the heat numbers cannot [illegible] identification is not complete. This must be made plain [illegible] be reported only for what they are worth.

[illegible] available, or where the client is not satisfied with the [illegible] of heat numbers, the only other way of determining

[illegible] but it must be made plain that this does [illegible] material, except the actual piece tested, when the [illegible] become a party to any of this testing of stock material [illegible] it is accomplished, that there is no complete [illegible] material and that we accept responsibility only accordingly. [illegible] It must be clearly understood by the contractor or shop [illegible] selection of test pieces from stock and the arrangements for testing of [illegible] at the expense; and we should not proceed until it is on record that this expense is to be assumed and accepted by somebody.

"(4) In the absence of any identification by record test or by the [illegible] of test pieces cut from the material, we can get a general idea of the quality by making bending tests on crop ends as the pieces are cut for finished lengths, [illegible] the employment of brittle material.

"(5) In considering the use of stock material under any method of testing, it should be carefully inspected by the shop inspector for surface defects; and any pieces that show signs of pitting from rust or that cannot be cleaned in a reasonably good manner for painting should be rejected.

"The above applies to main sections of material under stress. [illegible] fillers, connection angles, and other small pieces can generally be permitted to be used from stock without identification of quality by tests, if they are in good condition as regards surface."

Hildreth & Co. have evolved and patented a deformation [illegible] ought to prove valuable. The following is a description [illegible] to the author by the courtesy of that company.

"THE HILDRETH DEFORMATION TEST

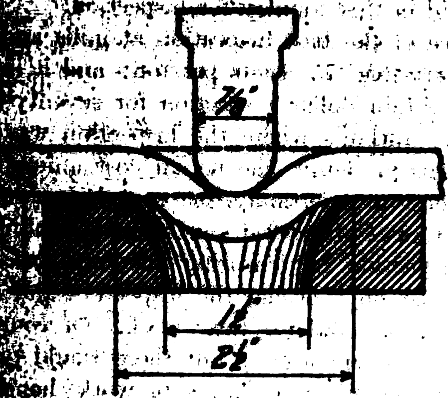
"(Patented)

"The established method of testing structural steel consists of [illegible] of the finished material from which test pieces are prepared to [illegible] furnace melt. The number of test pieces is generally one for [illegible] tension, and they may represent from fifty to ninety tons of [illegible] additional pieces are tested by punching, drifting, forging, or, in [illegible] opening out or closing down. This method of testing has been in [illegible] the commercial use of steel, and originally was valuable in [illegible] furnace charge. A number of years ago the condemnation of furnace [illegible] At the present time there has ceased to be any wide variation in the [illegible] is practically unknown that an entire furnace melt is condemned, [illegible] be of one grade of steel, whereas another has been specified. In [illegible] of steel in a furnace has been mastered and is now uniform in [illegible]

"As the steel industry has developed, greater attention [illegible] economies of manufacture and to the increase of tonnage, with [illegible] objectionable defects in steel arise, primarily, from the [illegible] from piping, which affect the finished product because of [illegible] and, secondly, from defects which occur because of too rapid [illegible] ingot, and from seams caused by metal over-lapping in rolling [illegible]

"It is not improbable that one hundred furnace melts [illegible]

[illegible] is conceived to determine the [illegible] at a point likely adjacent to where [illegible] and where failure is likely to occur [illegible] and conducted at the shop without additional [illegible] It has the special advantage of branding every [illegible]



Hildreth & Co.'s Deformation Testing Apparatus.

requiring the presence of an inspector or expert. It is par- [illegible] stock material where there are no records of the original furnace [illegible] it is impossible to cut test pieces of any size from the material. [illegible] such tests determine the theoretical tensile or other strength of [illegible] do determine general or local brittleness and demonstrate the [illegible] of the material.

[illegible] ⅞" punch is turned down to a hemispherical end. A [illegible] out to a die 1½" at bottom and 2½" at top, as per sketch; [illegible] being short is adjusted by washers or pieces of steel between [illegible] so arranged that the punch itself will travel below the [illegible] be tested a distance equal to the thickness of the metal. The [illegible] the base block of the punching machine.

[illegible] deforming the metal at a point between or adjacent to rivet [illegible] 2 inches. This deformity is carried to the extent of ½" [illegible] metal over ½" thick, the distance should equal the thick- [illegible] gives an excellent practical test of the working quality of the [illegible] punching and drifting test closely similar to tests of [illegible] will show by cracks on the convex surface. Tests [illegible] shop as the material is being punched and handled at an ex- [illegible] test. It is necessary that the 'Layer-out' shall indicate [illegible] for test so that it will not interfere with the riveting of

[illegible] testing apparatus.

[illegible] to pay for first-class inspection, the author [illegible] years ago he submitted to several of the

[illegible] inspecting bureaus a draft of [illegible] and duties, similar to those incorporated in this [illegible] that they tender upon inspecting for him, according [illegible] a large order of structural steel; and that the bids [illegible] one dollar to one dollar and twenty-five cents per [illegible] pounds. Subsequent experience has proved to the [illegible] spection as he then called for is worth fully one dollar [illegible] orders and a trifle more for smaller ones; although it [illegible] such a price is paid in this country for inspection.

Today the price of the best inspection at mills and [illegible] sixty (60) to seventy-five (75) cents per ton; and it is [illegible] cannot expect to obtain dollar inspection for seventy-five [illegible] large bridge of the author's where the inspection was done [illegible] cording to his ideals of detail, the actual cost amounted to [illegible] and three cents per ton. Certainly, the consulting bridge [illegible] the leading inspectors of structural steel should combine so as to [illegible] more thorough inspection by ensuring adequate prices [illegible] engineer should insist on choosing the inspectors and should [illegible] make the client foot the bill for their work. Of course, he [illegible] that the client is not overcharged; but there would probably [illegible] and fixed rates for the different classes of work, hence the [illegible] overcharge would not be likely to arise.

The following are Hildreth & Co.'s standard instructions [illegible] assistants concerning the inspections of steel rails and other [illegible]

"SPECIFICATIONS FOR INSPECTION OF RAILS AND THEIR [illegible]

"*Standard Tee Rails*

"In addition to the requirements of specifications, which are [illegible] be followed closely by inspectors, attention is called to the following [illegible]

"*Process of Manufacture.*—It is important that the Inspector [illegible] upon the details of the process of manufacture, for the reason [illegible] erally leave this to the manufacturer and that most of the defects [illegible] of efforts by the mill to secure increased tonnage and the [illegible] details of manufacture whereby good rails are secured. The [illegible] should be noted and whether it is being crowded to handle a [illegible] than its rated capacity, and also the time of melting. Pouring [illegible] should be slow; and the character of the tops of ingots should [illegible] specifications called for stirring the steel in the ladle with a pole to [illegible] to the surface. Bottom pouring produces ingots freer from gas [illegible] elements. Inspectors should watch such conditions so as to [illegible] the care used in pouring the ingots. The size of ingots and the [illegible] the ingot to the finished rail should be noted and an opinion [illegible] the steel is broken down too rapidly and the rails not well [illegible] between the saws should be watched as a check upon the [illegible] are finished, and this temperature should be noted. In [illegible] merely pass upon the finished rails but should watch and be [illegible] of the process of manufacture *and must report regarding them* [illegible]

"*Tests.*—All tests should be conducted by the [illegible]

should personally choose the test specimens so as to determine whether they fairly represent the material. They should particularly endeavor to find specimens which represent any material which is doubtful, and should try to get material which has been rolled from the top of the first and the last ingots cast from the ladle, so as, if possible, to obtain test pieces in which may occur segregated elements.

"*Section.*—The section of rail shall not only be checked in the mill; but when a final inspection is made of the rails, the templates shall be frequently applied so as to test the section of at least 25 per cent of the order; and should there be discovered any variations from the templates, then every rail must be checked.

"The same procedure must be followed with splice bars; and, in addition, several joints consisting of rails, splice bars, bolts, and nuts shall be assembled.

"*Length.*—Inspectors shall frequently check the standard length of rail, and they should not entrust such measurements entirely to the mill men. Complaints of railroads are frequent regarding variation of lengths; and such variation must be discovered and prevented.

"*Branding.*—The exact branding as it appears on the rails and splice plates should be reported, and it should be seen to agree with that required.

"*Drilling.*—Drilling should be seen to be accurate; and all ends of rails should be examined to ensure that the holes are free from burrs.

"*Straightening.*—The cambering of rails should be watched as well as the straightening, and no excessive gagging permitted. Short kinks shall class rails as No. 2. Every rail must be sighted for straightness.

"*No. 2 and Short Length Rails.*—Care should be taken to see that rails are properly classed and ends painted as specified. Inspectors should keep their own record of both classes of rails and short lengths.

"*Surface Inspection.*—Inspectors must make a thorough and careful inspection of rails by daylight, examining each rail for visible surface defects such as laminations, seams, fractures, scale, etc.; and they must particularly examine webs for evidence of piping. Every rail must be walked and examined on all sides.

"*Identification.*—All accepted rails must be plainly stamped on the end with our special brand; and each rail must be carefully and finally inspected before such acceptance.

"*Reports.*—Reports should be made immediately after shipment, showing rails accepted and shipped; and copies of shipping invoices should be sent with such reports. Inspectors should be particularly alert to see that no rejected rails are shipped, and should advise us at once if such is the case.

"*Night Inspection.*—Where large orders are rolled during the night, the Inspector in Charge should arrange either to be personally on the work or to have an assistant present. Where large orders require several men at the mills, the Inspector in Charge will so advise us, so that sufficient assistance can be provided.

"*Special Notes for Girder Rails*

"In the inspection of girder rails, particular attention shall be given to see that the groove is absolutely straight and that the head is full where the tread of the wheel runs and at the points of bearing of splice plates. Special attention should be given to see that the height of rails is accurate and that the sections of joints correspond closely.

"*Splice Plates*

"See 'Process of Manufacture' and 'Tests' for Rails.

"*Bending Tests.*—Must be made as required and reported by outlining on report forms for tensile tests or on plain white paper of the same size as the reports.

"*Section.*—Must be carefully checked by templates.

"*Punching.*—Must be accurate and tested by templates. All burrs must be re-

[illegible]

“Bolts and Nuts

“[illegible] keg of bolts and nuts must be seen and the [illegible] are clean-cut and full. Numerous nuts must be [illegible] of thread (such as Whitworth's Standard for foreign [illegible] followed. Bending tests must be made as per specifications. [illegible] made by filling up between head and shoulder of threads [illegible] the nut on with a long-handled wrench. Bolts must twist off [illegible] All dimensions must be checked. Bolts tested by bending [illegible] placed on top of contents of keg to demonstrate that inspection [illegible]

“Spikes

“All dimensions must be measured and every keg opened [illegible] tested by bending should be sent with shipment as for bolts. [illegible] be full and points clean-cut and sharp. Samples must be tested [illegible] turn without fracture.

“Nut Locks

“Nut locks must agree with dimensions and quality specified. [illegible] be done in oil. Samples chosen at random must be tested by being [illegible] forcing one end ⅛" clear beyond the opposite end. If it breaks or [illegible] set, additional tests must be made, acceptance refused, and the facts [illegible]

A short time ago when calling at the New York office [illegible] John D. Isaacs, Esq., C.E., Consulting Engineer to the [illegible] Railway Company, etc., the conversation turned to the [illegible] inspection, and the author stated (as he had on many previous [illegible] to others, but had been contradicted) that, in his opinion, [illegible] costing only five cents per ton is entirely inadequate, and [illegible] inspection would cost several times that amount. Mr. [illegible] that he had had a similar opinion for many years, and [illegible] years previously he had called in Messrs. Robert W. Hunt [illegible] well-known inspecting bureau, and insisted that they [illegible] him with a rail inspection which would cost much more. [illegible] and the result was very gratifying; for the rate of breakage [illegible] forthwith reduced to a small percentage of what it had been. [illegible] Mr. Isaac's story was so interesting that the author requested [illegible] repeat it in writing for use in this book. He very kindly [illegible] on October 15, 1915, wrote as follows:

“As a result of our study of rail failures occurring on [illegible] became convinced that the reasons for many failures of a [illegible] and section of rail, of which weight and section we had [illegible] that were giving good service, must be due to lack of [illegible] practice or to improper methods used which generally [illegible] tected by the methods of inspection in force. This [illegible]

[illegible] with the methods used by the [illegible] quality to quantity of [illegible] matter we evolved the idea that if we [illegible] as to cover the rail during all stages of [illegible] greater control over, or, at least, greater [illegible] finally submitted for our acceptance. [illegible] part of 1912, we took this matter up with [illegible] submitted to us, under date of March 18th, 1912, [illegible] details of the special rail inspection which [illegible]

[illegible] night and day in either the Converting Works (if Bessemer) [illegible] of that material), a man night and day in the Blooming Mill [illegible] and day in the Rail Mill, a man night and day at the Testing [illegible] on the inspection and shipment of the finished rails, making

[illegible] department the men will observe and make note of the [illegible] of steel, as to when the recarboniser is added, the [illegible] held in the casting ladle before being teemed into the moulds, [illegible] in the casting ladles, the length of time occupied in conduct[illegible] the condition of the moulds as to smoothness, etc., and the [illegible] the stripping machine—in other words, to have a general [illegible] transpire in the steel producing department.

[illegible] the inspectors will observe and note the length of time the [illegible] pit, the temperature at which they are rolled, and the [illegible] being so rolled—also as to the amount of cropping which [illegible] etc., etc.

[illegible] inspectors will observe and note the distance at which the saws [illegible] the temperature at which the rails are finished, note as to the [illegible] care with which the rails are stamped, not only as to [illegible] to their relative positions in the ingots from which they [illegible] amount of cambering which is given the rails, and their [illegible]

[illegible] drop testing machine will observe and record the behavior [illegible] testing, while the four other men will have charge of the final [illegible] as to straightness, accuracy of drilling, freedom from flaws, [illegible]

[illegible] men in all.

[illegible] that while these men will be present day and night [illegible] of the Works, they will not have power or authority to [illegible] of the mill; but, based upon their observations, if any [illegible] their judgment, may be prejudicial to the production [illegible] the inspectors who have the final passing upon the rails [illegible] rails made from the said heats or else to give them extra [illegible] for rejection, the said rails can be put aside for dis[illegible] authorities and for final acceptance or permanent rejection, [illegible]

[illegible] thoroughly to police the plant during the production [illegible] influence tending toward careful work upon the [illegible] plant."

[illegible]

Further descriptions of this special
way Engineering Review, November 23, 1912,
Gazette, March 17, 1915.

"The foregoing, together with the report
tion, report of chemical and physical examination,
reports, copies of which I enclose herewith—should
standing of the matter.

"Our adoption of this special inspection in 191
by many other large roads, until in 1914, as stated in
above referred to, 78 per cent of all rails inspected by
& Co. were given the special inspection.

"The direct benefits to be expected are:

A more thorough compliance with our specifications.

A more careful superficial examination.

More thoroughly to insure proper discard so
metal.

"Should there be a departure from known good practice
liminary manufacture of the rails, although this could
by the inspector, it would enable him to give especial
manufactured under these irregular conditions, rendering
poor rails more certain.

"The indirect benefits which are to be expected are:

"A more thorough knowledge, by study and compar
mill methods, of what is the best current practice in
of the art.

"Having a complete history of the manufacture,
vice be obtained from these rails, a study of any irregul
facture may lead to a solution of some of our troubles.

"On account of interruptions during the manufacture,
irregularities often occur; and the moral effect of having
throughout the mill will doubtless lead to more care on
mill operatives to avoid departure from what is
Practice.'

"There has been a marked improvement in quality
by us during the last few years. This improvement

1. "Improved mill practice, giving a rail more
defects.

2. "Improved rail sections, better distributing
uniform rolling temperatures.

3. "Improved distribution of the chemical
segregation and more homogeneity of material,
rail failures from brittleness.

4. "More thorough inspection."

"It is impossible to segregate the improvement
special inspection, but we do know that certain

times in the past and which have
of the rail can not 'get by' under the new
that the special inspection is well worth the
cost."

Mr. Isaacs for his courtesy, the author requested
percentages of breaks before and after the radical
adopted, as mentioned during the conversation
Mr. Isaacs very modestly refused on the ground that
was not due to the said change but somewhat
the art of manufacture. To quote his own words:
the number of breaks per ton of rail because it makes
that the entire improvement is due to new methods
is not the case, as there was a marked improvement
of such inspection; and, therefore, a statement of
as a matter of fact, does not give sufficient credit
the art of manufacture, due partly to this and partly
mill men to improve their output.

to my letter to you of the 15th inst., you will note
to the impossibility of segregating the improve-
inspection; and further than this I am not willing
a definite statement as to effect produced, whatever
it may be.

to say is that special inspection is one of the im-
causes to improvement in manufacture of rails."

the preceding that Mr. Isaacs by inaugurating
has made an important advance in American

of materials and workmanship in the field,
which the author has prepared for his field
inspectors, will be found to cover the subject

(A) METALWORK

the greatest care all of the metalwork as fast
make sure that it has not been injured during
an eye on it thereafter to see that it is not
See also that there are no missing parts.

metalwork goes together properly and expe-
the Engineer all necessity for chipping or filing

the riveting to see that no burnt rivets are
driven in accordance with the specifications,
left in the work. The inspector should keep
of the air compressor, and should also see

[illegible] should be [illegible] driving seven-eighths (⅞) inch [illegible] in length. For one-inch rivets [illegible] pounds per square inch should [illegible] should be taken in heating rivets to [illegible] end to be driven being heated to a cherry [illegible], the rivet will flow back into the hole, [illegible] the head will form accurately with no tendency to [illegible] if it be too hot.

All mill scale should be removed from the [illegible] driving.

A pneumatic "dolly" to hold over the round [illegible] being driven gives very good results, and should be [illegible] are long and must grip several thicknesses of metal. [illegible]

In driving nickel-steel rivets or extra long carbon-[illegible] to use a pneumatic hammer at each end while driving. [illegible]

Fourth. See that all vacant spaces in the [illegible] filled with paint-skins or other water-proof material [illegible] is begun.

Fifth. In elevated-railroad work see that during [illegible] metal the lengths of the girders are sufficiently [illegible] possibility of using up the spaces provided for [illegible] greatest temperature of the metal to be one hundred [illegible] degrees. See also that the expansion and contraction [illegible] cannot injure the stairways.

Sixth. In drawbridges, see that the masonry of the [illegible] levelled off with the greatest accuracy, and that the lower [illegible] are set to exact position and level, thus making a [illegible] surface for the rollers. See also that the latter are [illegible] bear evenly at top and bottom against both upper [illegible] segments.

Seventh. See that the ends of draw-spans are properly [illegible] means of the shimming-plates on the rest piers. Make [illegible] particular the draw is reversible end for end; and see [illegible] is properly aligned so that there will be no binding in any [illegible]

Eighth. See that, before the operating machinery is [illegible] ing or rolling surfaces are thoroughly lubricated, and that the [illegible] cleared of all obstructions, such as nails, etc., on the lower [illegible] Then operate for a while and make a test of the [illegible] compute therefrom the horse-power required to operate [illegible]

Ninth. In vertical lift bridges see that the towers [illegible] position, and that all the machinery is located true [illegible] also that it is thoroughly lubricated. See that [illegible]

[illegible] special paint [illegible] and [illegible] the machinery, and make the [illegible] balanced as possible, paying due attention [illegible] counterweight concrete. In respect to the machinery [illegible] 8 and 9 given for swing spans and vertical lift [illegible] all anchor bolts are set in exact position and [illegible] they are properly grouted in. Be careful [illegible] for locating them are put in, the mistake of turning [illegible] from correct position is not made.

[illegible] the bearings or skew-backs for arches, take the [illegible] centres are set to exact position and elevation, and [illegible] the metalwork on the masonry are perfect.

[illegible] there are any adjustable rods used in a [illegible] are properly tightened before the work is left, taking [illegible] not screwed up more than is really necessary.

[illegible] reinforced concrete work see that all reinforcing bars [illegible] for the various places, that they are put in correct [illegible] they are held therein so firmly that they will not be [illegible] concrete is being placed around them. See that as [illegible] removed the concrete exposed thereby is given its [illegible] delay, for such work can then be done at compara- [illegible] while later the cost is likely to be excessive.

(B) RAILS

[illegible] all rails as soon as received, so as to see that there [illegible] which have escaped the rail-inspector's eye, or which [illegible] for shipment after being rejected. Inspect also all [illegible] such as angle-bars, bolts, and braces, so as to see that [illegible] type and are delivered in good shape.

[illegible] all rails are laid to exact line and level, that they [illegible] where, and that they are properly spiked.

[illegible] spans, make sure that the track-rails at the ends [illegible] the operation of the span.

[illegible] rails are to be bonded, see that the bonding is [illegible] with the specifications.

(C) PAINTING

[illegible] proper cleansing, drying, and retouching with [illegible] its first field-coat of paint as soon as prac- [illegible] the next coat is applied as soon as prac- [illegible] is thoroughly dried, but in no case before. [illegible] all paints used are of the proper color, qual-

[illegible]ity and consistency, and that no [illegible] that all paint is properly applied. [illegible]

Third. Look carefully to the painting of all [illegible] and see that it is done effectively with a piece of [illegible] specifications.

Fourth. See that all portions of the metalwork [illegible] on the masonry or which are to be embedded in [illegible] their two field-coats of paint in due time, so as to dry [illegible] the said metalwork is erected.

(D) EXCAVATION

First. Watch carefully all excavation so as to make [illegible] done in strict accordance with the specifications and [illegible]nances, if there be any. See that, in doing the excavation [illegible]ing the structure, the Contractor does not obstruct public [illegible]

Second. In foundation-work in cities, see that all pipes [illegible] are moved properly and coupled or spliced effectively after being [illegible] or cut.

Third. Whenever there is any doubt about the proper [illegible] any foundation, test it by loading it by means of a properly [illegible] and built apparatus. Always ram thoroughly any foundation [illegible] resistance to load would be effectively increased by such [illegible] that the material from the sides of the pits is prevented from [illegible]

Fourth. See that all surplus material is removed expedi[illegible] City streets, and that, whenever any piece of construction is [illegible] all falsework, rubbish, etc., are removed from the site and [illegible] in an unobjectionable place.

(E) FOUNDATIONS

First. See that the bed-rock is always properly [illegible] the caisson or masonry, as the case may be, letting the [illegible] rock so as to provide an even bearing around the cutting [illegible]elling or stepping off or filling up with concrete to receive [illegible]

Second. In elevated-railroad work, see that wherever [illegible]cated in the street their feet are properly encased in [illegible] cast-iron fenders are correctly set around the columns [illegible] concrete and grouting, then sealed effectively against the [illegible] See also that, after the columns are up and encased, the [illegible] laid in a substantial manner, to the satisfaction of the [illegible]

Third. When large steel cylinders are used, see [illegible] well braced with timbers on the inside during sinking [illegible] all possibility of collapse.

Fourth. See that proper guides are provide[illegible]

[illegible] be kept in exact horizontal position during
[illegible]

[illegible] tops of all piers are properly finished off to receive
[illegible] care that all bearings are made perfectly smooth
[illegible]

(F) CAISSONS

[illegible] timber caissons, see that the plans are followed
[illegible] full quantum of timber bolts is used; also, that
[illegible] not put in where long ones are called for. See that all
[illegible] framed.

[illegible] caissons, see that they are never allowed to devi-
[illegible] correct position, and that all errors of position are
[illegible] possible after they are discovered.

[illegible] working-chambers of caissons, see that the concrete
[illegible] against the roof, and that no voids whatsoever are left
[illegible]

(G) CEMENT AND CONCRETE

[illegible] the cement, according to the special instructions there-
[illegible] is needed for use that the Contractor shall not be
[illegible] testing.

[illegible] all cement is properly housed and blocked up above
[illegible] barrels, that the latter are laid upon their sides, also
[illegible] other necessary way protected effectively from the
[illegible] that no dampened or otherwise injured cement is
[illegible] the work.

[illegible] as soon as delivered, and if possible before being dumped
[illegible] sand and broken stone, so as to make sure that they
[illegible] with the specifications; and insist always upon
[illegible] that are rejected being removed immediately from
[illegible] site. If there be any doubt whatsoever about
[illegible] sand for mortar and concrete, make a mechanical
[illegible] the gradation of grains, and prepare and test suf-
[illegible] to settle the matter beyond the peradventure of
[illegible] the stone also should be subjected to mechanical
[illegible] be any doubt whatsoever about the quality of
[illegible] test cubes or cylinders should be made from the
[illegible] at the end of seven and twenty-eight days.

[illegible] and proper forms for concrete are used in the
[illegible] pedestals, and abutments, and that all visible
[illegible] finished off smooth, the top surface being brought
[illegible] perfectly level.

[illegible] is mixed according to the specifications,
[illegible] after mixing, and that it is thoroughly
[illegible] surface as specified.

[illegible] permit the removal of forms [illegible] [illegible]

[illegible]. When concrete is placed under [illegible] tremie or proper collapsing-bucket be used, and [illegible] permitted to injure the concrete. See also that [illegible] extra rich. Make sure that the tremie is kept [illegible] concrete.

(H) PILING AND [illegible]

First. See that all piles conform, in size, quality [illegible] with the requirements of the specifications, even if [illegible] passed by the timber inspector before shipment, and [illegible] unfit for use.

Second. See that all piles are driven straight and in [illegible] and that the tops are not unduly injured in driving, having [illegible] banded whenever necessary to prevent splitting. [illegible] split or driven at incorrect location are drawn and [illegible] to correct location as the case may be.

Third. See that all piles are cut off level at the [illegible] quired, and that the caps are properly drift-bolted [illegible] see that the superelevation is obtained properly, and [illegible] up on the caps.

Fourth. See that all sway-bracing is bolted [illegible] and caps.

(I) TIMBER, FLOORING, AND HAND-RAILS

First. Inspect all timber as soon as delivered, [illegible] rejected pieces; and see that all such pieces are removed [illegible] ity without delay, in order to prevent their being put [illegible] without the knowledge of the resident engineer. It is, of [illegible] sible to use the good portions of rejected timbers; but [illegible] care should be exercised to prevent the workmen from [illegible] material into the work. The fact that all the timber [illegible] previously accepted by the timber inspector is no [illegible] isfactory material; moreover, sometimes it happens [illegible] the inspector has never even seen are marked with his [illegible]

Second. See that the floor system is properly [illegible] the metalwork, that each rail bears effectively upon [illegible] crosses, and that the rails are laid straight, evenly, [illegible]

Third. See that the hand-railing is brought to [illegible] is held there in a permanent manner.

Fourth. See that all joists in highway bridges [illegible]

[illegible] the top flanges of the floor-beams, [illegible] abut and run continuously, and that [illegible] the inside.

[illegible] joists in which the depth exceeds four times the [illegible] distances not to exceed eight feet, and that [illegible] depends for its rigidity upon that of the [illegible] bridged and otherwise stiffened where the [illegible]

[illegible] alternate bolts attaching guard-rails to floor-[illegible] and the outer joists, and that all holes through [illegible] in the central plane of the joist and not too close to [illegible]

(J) Masonry

[illegible] stone as soon as received, so as to see that it has [illegible], and that it is satisfactory in every particular, [illegible] been passed by the stone inspector.

[illegible] all stones are thoroughly cleaned and wet before [illegible]

[illegible] all mortar is mixed in the proper proportion, and [illegible] work before any set has occurred.

[illegible] all joints are thoroughly filled with mortar, grout [illegible] prohibited, and that the vertical joints are filled by [illegible] sure that no voids are left anywhere in the entire [illegible]

[illegible] all coping-stones are set so that the top of the pier [illegible] horizontal plane, and that they are kept in place by [illegible] dowels as per plans.

[illegible] the exposed joints are all cleansed and pointed in a [illegible] manner, and in accordance with the speci-[illegible]

(K) General Instructions

[illegible] proper precautions against accidents to the public [illegible] be taken during erection, and that no glaringly [illegible] on the work.

[illegible] more than one contractor on the job, see that [illegible] contractors, and that their combined work is [illegible]

[illegible] everything in your power to obtain good work, [illegible] worrying or harassing the contractor, and use [illegible] to aid him to complete his work expeditiously [illegible]

Fourth. Finally, and in short, [illegible]
do all that you can to ensure the structure's
to all concerned in its designing and

(L) CEMENT

In respect to the testing of cement on
instructions, which the author has prepared for
will give the reader all necessary information, it
far as is possible, no brands of cement are used except
the author or his assistants have previously tested
time tests, and which have proved to be perfectly

First. In testing cement in the field, remember
of laboratory tests which you are to make, but that your
to see that you are receiving and using cement of an
the standard brand or brands adopted, and that it comes
eral requirements of the specifications.

Second. Look out for irregularities in the quality of
as to avoid using any that is either too old or too fresh, or
injured by dampness.

Third. Test first for fineness, second for soundness, third
and fourth for rise in temperature, rejecting all cement
for use because of non-compliance with the
particulars.

Fourth. Make also the boiling test as specified in
for if any cement fails to comply with its requirements,
use, unless, perchance, it may be improved by ageing.

Fifth. Test all cements for the tensile strength of
making one-day and seven-day tests. Never pass cement on
tests than seven days, as the one-day test is by no

Sixth. Make, more for your own satisfaction than for
reason, a few sand-briquette tests for seven and twenty-eight
to know the value of the mortar which you are using. It
to rely on sand-briquette tests for the acceptance or rejection
as this would delay the work too much.

Seventh. You will often have to use your judgment
rejecting cement that is needed for immediate use
some comparatively unimportant point quite to fill
the specifications. Rather than delay the contractor
such cement, provided that in your opinion its use
the quality of the work; but, on the other hand,
said cement will not delay the contractor seriously,
ing with the specifications in every particular.
contractor run in any poor cement or force it
assumed or real necessity for haste in completing

STONE FOR MASONRY

tion of stone for masonry, the author offers, as his
inspection should be, the following instructions to
being understood that they apply only to stone from
previously been investigated and found satisfactory:

all stone containing any dry seams. These seams are
detect; but usually by a careful inspection of the sur-
they may be found. Sometimes a mere line is all the
existence of such seams. while in other cases they show

all stone containing seams called "crow-foot," which
or which are liable to dissolve out after exposure to the

that no stone is quarried at a time when it is liable to
quarry-sap is out of it. Stone should be quarried at
before it is allowed to freeze.

that no powder or other explosive is used in quarrying
to remove ledges of useless stone, and even then
stone to be used is injured by the explosives.

stone be of such a character that the quarry-bed cannot
the inspector must mark each stone in such a manner
to be laid in the wall on the said quarry-bed.

all stone which is taken from any portion of the quarry
at any time by frost.

that all stone is handled carefully after being taken
that no cracks are developed or other injury done

that all stones are cut to the exact dimensions called for
that they comply in every particular with the speci-

TIMBER IN WOODS AND AT SAWMILLS

of timber, both in the woods and at the saw-
instructions to his timber-inspectors, as follows, will

and compare with the mill people all order-bills,
various lengths, widths, thicknesses, bevels, num-
to make sure that your order-bills check properly
to the mill people and against the partial order-
to their various employees, so as to avoid
If any be found, correct them yourself, if possible,
the Engineer for correction.

inspector is to be provided with a special stamp-
has a characteristic mark which will identify

[illegible]

[illegible] timber inspector must [illegible] him, and must be governed thereby [illegible] when he must trust to his own judg[illegible] and what is unfit for the required purpose [illegible] be made broad enough to cover all [illegible] timber bill. Where a number of inspectors are [illegible] of work, it will be necessary at the outset [illegible] to interpret the specifications and supplementary [illegible] the assistant inspectors, so that the latter shall not [illegible] requirements.

Fourth. When inspecting timber be careful to [illegible] between the various varieties that are fit and those [illegible] use. If not otherwise stated in the specifications, you [illegible] reject as follows:

Oaks

Accept white, cow, chincapin, post, burr or overcup, [illegible] Reject red, Spanish or water, black, black-jack, and [illegible] oaks.

Pines

Accept white, Norway, long-leaf Southern yellow, [illegible] (for certain purposes only), and Cuban pines; also Oregon [illegible] Southern-red, loblolly, and Rocky-Mountain yellow pines, [illegible]

Cypress

Accept red, black, and yellow cypress. Reject white cypress [illegible]

Fifth. Secure timber of as uniform a character as possible, avoiding any that shows large heart-checks or growth-checks, and rejecting any which has such defects of minor importance within one inch of face or edge of timber. Avoid all coarse-growth, open-grained timber, if other timber be procurable.

Sixth. Reject any sticks that show signs of worm-holes, [illegible] scorching by forest fires, ring-heart, ring-shakes, rotten or black knots, dark or discolored spots, or any other defect that would impair the [illegible] or durability of the timber.

Seventh. Examine carefully by probing with a wire all hollow [illegible] eye knots, and should the hollow be over one inch deep, reject [illegible]

Eighth. Check lengths of cutting gauges every day, as [illegible] occasionally to be knocked out of position. Check [illegible] at each change of the machine [illegible]

[illegible] and in every other particular with the [illegible]

[illegible] care is used in handling and loading timber [illegible] under no consideration allow it to be [illegible] and dressed.

[illegible] daily record of all timber accepted, so that [illegible] on short notice as to how much of any [illegible]

[illegible] Engineer or other proper party of all shipments [illegible] account of everything shipped, so that upon [illegible] respect to any uncompleted order can be [illegible] has been shipped and the amount that remains [illegible]

[illegible] Chief Inspector must make regular monthly reports [illegible] other proper party or parties concerning the progress [illegible] of timber furnished, etc.; and must send in monthly [illegible] moneys received and expended by him in connection [illegible] inspection.

[illegible] every endeavor not to cause by your inspection any [illegible] material than is necessary for doing your work thor- [illegible] to give the mill people needless worry or expense.

[illegible] chapter, the author desires to emphasise his pre- [illegible] that, in order to obtain a truly first-class structure, it is [illegible] to design it properly and prepare thorough specifica- [illegible] but also to provide a corps of competent and honest [illegible] from start to finish, will examine carefully and test all [illegible] to be used, and who will see that the entire manufacture [illegible] in strict compliance with the specifications.

CHAPTER LX

TRIANGULATION

THE necessity for extreme accuracy in the
long bridges is not generally recognised; hence result
tion that sometimes require the lengthening or
structure, or which involve the adoption of an
is no excuse whatsoever for any such errors in location,
of triangulation adopted should provide a check against
but also even trifling variations from correctness of
the Contractor should invariably, at the outset of
precautions as will prevent the occurrence of any
in excess of that provided for in the Engineer's plans.

In the triangulations for bridges over large rivers,
souri, the author makes a practice of measuring each
and each angle thirty times; and no point is ever located
a check from another base-line, thus providing an
lines, which theoretically should be a mathematical point,
tually varies therefrom, generally about a quarter of an
times even as much as one-half of an inch, in sights of
feet length.

The author has tried both iron rods and steel
base-lines, and has adopted the latter as the more
tion to using rods is that it is almost impossible to run a
feet long with three rods that must always be made
each other without sometimes disturbing slightly the
the rods, when either lifting or putting down the third
liable steel tape properly handled, the extreme error in a
surements of the same line should be less than one-quarter
one thousand feet. This would make the probable
length considerably less than that amount. If any
greater variation from the average than one-quarter
thousand feet, it should be rejected, and another
be made to replace it. This presupposes
the base-line; hence, if the ground be very irregular,
may be allowed. It should, however, in no case
per thousand feet.

The tape-line used should be a new one for
should be tested at the bridge shops, in comparison
As a matter of precaution, it is well to test it in

as a reserve and not used unless an accident
tape. For very long and important bridges
long spans, it would be well to have the tape
of Weights and Measures at Washington, D. C.,
bureau of recognized standing—such, for instance,
ington University at St. Louis, Mo. The charge for
merely nominal. As the coefficient of expansion is
tapes, it might be advisable for extremely accurate
coefficient determined for the tape to be used; but in
span bridges this would be an unnecessary refinement.
long enough, and is in many respects preferable to
length. The author has not much use for extremely
distances directly between pier centres either dur-
the piers are finished, because this method of mea-
means as accurate as that of intersecting three lines
two independently measured based-lines. There
measurement to make correctly than one with a long
two distant points without intermediate supports;
place, the double measurement on shore and in cor-
and tedious one to make, involving as it does the
obtain the sag, which must be exactly alike in both
second place, the conditions of wind and temperature
such an extent as to cause errors that are very dif-
only direct measurement that is of any real value,
obtained before the falsework is up, is one made on
measurement care must be taken not to let the tape
to rest it on plugs driven on perfect line into holes
exact level.

urements should be made in cloudy weather, or just
at night; and the temperature should be noted for
as all lengths must be reduced to those for an
temperature of seventy degrees Fahrenheit. Even
temperature will cause errors of importance in the
base-line, the change in length per degree of tem-
of length being about 0.0000066. For a base-line
and a variation of one degree the change in length
dredths of an inch. This, it is true, is no great
always a liability of there being a difference of as
between the average temperatures for measurements
days, and as much as two or three degrees in a
base-line. In using a steel tape it is better to
rather than from the end, unless the ring
point.

measuring a base-line on comparatively level
stakes of at least three inches by one inch

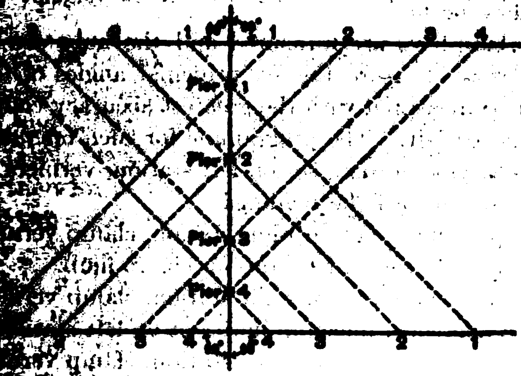
section and from two feet upward in length, spaced at intervals of about ten feet and put into exact line and level, with a large flat-headed tack driven to line on each stake and the true base-line determined by the instrument and scratched with a knife along the top of each tack. The line is measured by stretching the tape with a uniform pull of six pounds over the line of stakes, keeping the one-foot mark or the zero-mark, as the case may be, over the centre that is cut on the hub at the end of the base-line, and scratching with a knife on the tack where the fifty foot mark on the tape comes, then starting from this point to measure another forty-nine or fifty feet, and so on until the centre of the hub at the far end of the base-line is reached. The next time that the line is measured the first length should be thirty-nine or forty feet, so as to avoid using the same tacks; and each succeeding first length should be ten feet shorter. This not only involves the use of fresh tacks for each measurement, but also prevents any manipulation of the tape so as to make the partial measurements agree with those made previously. In case that a perfectly level line cannot be obtained, the line should be divided into level stretches, and where each break occurs the length should be measured on the incline and corrected afterward for the effect of the rise or fall so as to obtain the true horizontal distance. For further directions as to measuring base-lines with a steel tape, the reader is referred to Johnson's "Theory and Practice of Surveying."

The ends of base-lines, as well as all intermediate points from which triangulation operations may be conducted, should be marked by solid and secure hubs. In protected places these may consist of six-inch by six-inch timbers, three feet or more in length, driven in the ground and cut off about an inch above the surface, the centre being marked with a tack, across which are cut two intersecting lines at right angles to each other.

If the ground be subjected to hard freezing, the timber should be increased in section to eight inches by eight inches, and the length should be such that it will penetrate the ground, if possible, about three feet below frost. The earth around the hub location should be excavated to the greatest depth of frost, then the timber should be driven in or sunk like a post and well tamped, after which a stout timber box with an open bottom and a strong cover should be placed around the hub, and the earth should be packed around the outside thereof. Finally the box should be filled nearly to the top of the hub with sawdust or dry sand. In case that the ground be very hard, or if the bed-rock be near the surface, it will be best to surround the hub with concrete, and protect it with a substantial cover of some kind to prevent displacement. If driving or carting is to be carried on in the vicinity of the hub, the latter should be fenced in by four stout posts sunk into the ground on the corners of a square of seven or eight feet on a side, the posts projecting high enough above the ground to strike a wagon-box. In locating all triangu-

[illegible] will be disturbed by the [illegible] such hubs should be [illegible] some distance away. This should [illegible] mounted.

[illegible] two base-lines, one on each side of the [illegible] side of the bridge, or both should be on the [illegible]



[illegible] Ideal System for Triangulation.

[illegible] one above and the other below the bridge. Usu- [illegible] satisfactory to locate all piers from one point on each [illegible] reason the ends of the base-line should be chosen [illegible] all the piers can be seen therefrom. If this be im- [illegible] of the deflections would for any reason be too small, [illegible] put in and use intermediate hubs on the base-lines. [illegible] it is practicable, should be run approximately [illegible] longitudinal axis of the bridge; but this is by no [illegible] it is folly to try to make the intersection exactly at [illegible] in the following case, which represents an ideal sys- [illegible] that can rarely be utilized, on account of the existing [illegible] and obstructions both natural and artificial.

[illegible] consists in running four base-lines, as shown in [illegible] right angles to the centre line of the bridge, and [illegible] ances equal to those from the base-line to pier [illegible] of sight will intersect the centre line at angles [illegible] The advantage of this system lies in the [illegible] located by direct sight without having to measure [illegible] requiring measurement being the four right [illegible] and the centre line of bridge, and the four [illegible] determining and checking the distance between [illegible] tangent.

The lengths of base-lines for ordinary
generally be regulated by local conditions.
as long as the total length of bridge, or, when the
side of the river, as long as the perpendicular
base-lines; but, if necessary, they may be made as
of the same. Too short base-lines will give too
therefore sometimes too great variations from
sharp intersections can be employed at times by
the work and by employing an extra intersection as a
any discrepancy occur.

After the base-lines are measured and the hubs
step to take is to measure the six principal angles of the
These should be measured with the greatest accuracy
the limb of the transit. The programme for such

1. With telescope normal, set on left station, verniers
both verniers and record the readings.
2. Unclamp verniers, set on right station, clamp verniers
3. Unclamp limb, set on left station, clamp limb.
4. Unclamp verniers, set on right station, clamp verniers
5. Reverse telescope, unclamp limb, set on left station
6. Unclamp verniers, set on right station, clamp verniers
7. Unclamp limb, set on left station, clamp limb.
8. Unclamp verniers, set on right station, clamp verniers
9. Read both verniers. Record the readings. Divide
by four for mean value. Leave verniers clamped.

1. Place telescope normal, loosen limb. Set on right
verniers and record readings as a check against the
slight displacement.
2. Unclamp verniers, set on left station, clamp verniers
3. Unclamp limb, set on right station, clamp limb.
4. Unclamp verniers, set on left station, clamp verniers
5. Reverse telescope, unclamp limb, set on right station
6. Unclamp verniers set on left station, clamp verniers
7. Unclamp limb, set on right station, clamp limb.
8. Unclamp verniers, set on left station, clamp verniers
9. Read verniers and record. Divide total angle by
value. Take average of these two means for provisional

Then set the verniers ahead on the limb to some
approximating the value just determined, so as to use
the graduated circle, and repeat the foregoing programme
ing another provisional mean value of the angle
the verniers further ahead on the limb to some convenient
the same value as before and repeat the operations
of the transit has been utilized. An average can
several provisional mean values thus obtained, and

angle. To attain accuracy the limb of the
graduated as fine as twenty seconds or, preferably,
instrument with a good solid tripod will usually give
those obtained by using a lighter instrument. The
permitted to shine on the instrument when the angles
as it is impossible to make accurate measurements

of triangulation-work a record should be made of
temperature, the condition of the weather, the direction
velocity of the wind, and the names of the transitman

are to be taken, the picketman should be provided with
to enable him to see the transitman's signals; other-
and labor may be spent to no purpose. Long sights
taken toward the sun when it can be avoided.
the sum of the angles in each of the two main triangles
seconds in important work. Of course it is not neces-
such refinement in short-span bridges; but in very long
well be reduced as low as one second. If the error in
too large, it may be possible to avoid measuring all
by looking over the notes and ascertaining from the
which angle is most likely to be at fault, then measur-
If the second average angle reduces the total error
within a proper limit, all right; but if not, the other
have to be measured a second time. On the same
group of measurements of one angle, one or two read-
differ greatly from the others, they may be thrown out
the average.
happens that both intersections of the bridge tangent
cannot be seen from one end of one of the latter. In
necessary to put in a hub on the bridge tangent far
the hidden point to clear the obstruction, triangulate
the exact distance from it to the hub on the base-line.
necessary in the triangulation for the author's Jef-
bridge.
somewhat complicated triangulation is a layout lately
author for his proposed Havana Harbor Bridge. As
the bridge tangent *AB* cuts the wharf of the Havana
its outer end, thus affording a long base-line *BC*
southeast side of the said tangent; but no base-
on the northwest side thereof. At the other end
quite obliquely the face of a wall *DE* about
the water and about fifteen feet above the ad-
a base-line *AF* about 700 feet long can be
of this base-line with the bridge tangent at

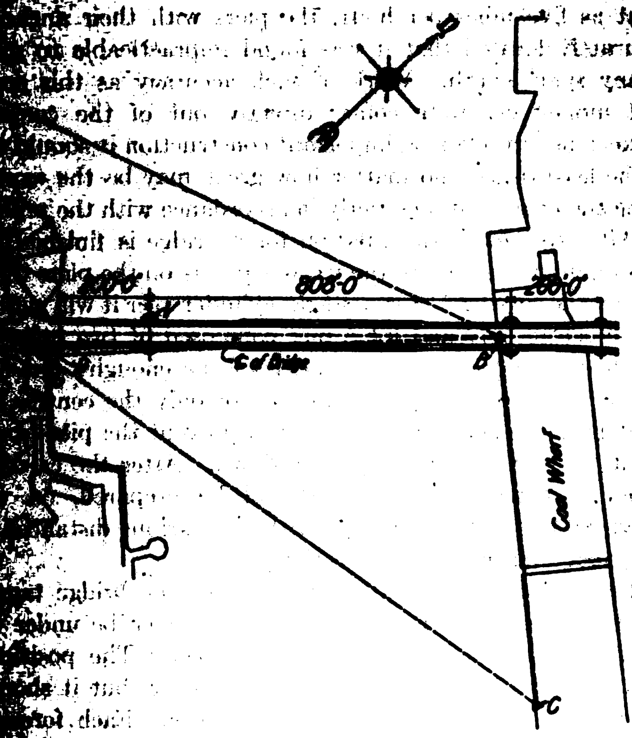
[illegible] to sight over the [illegible] of the bridge tangent with the long [illegible] three feet below its top is a [illegible] measurements may be made by taping. A[illegible] wall is to be located an auxiliary triangulation [illegible] far end C of the base line BC. All the angles of [illegible] GBC are to be measured. If G proves to be [illegible] all the angles of the triangle ABG and the side AG [illegible] otherwise a point H on AB near the face of the [illegible] that all the angles of the triangle HBG and the [illegible] The distance AH can be obtained directly by [illegible]

The length AB can be calculated by two differ[illegible] a check, viz., by the triangle ABF, and by the [illegible] G is visible from A, or otherwise by the triangle HBG [illegible] measurement of AH. The main pier near B, occupying [illegible] wharf, will be located by direct measurement, and the [illegible] D by instruments at F and G; while the other main [illegible] 200 feet outside of the wall at V, can be located by [illegible] and C, provided there be no vessels along the wharf [illegible] provide for such a contingency an intermediate transit [illegible] cated on BC, and a short base line GI can be run along [illegible] to turn off an angle of about forty-five degrees in locating [illegible]

A check on the accuracy of any triangulation work is obtained by comparing the two (or more) computed lengths of the [illegible] between the intersections thereof with the base lines, or between [illegible] such intersection and a fixed point on the tangent on the other side of the river. The disagreement in these two measurements should be within the limit of one-half of an inch to one thousand feet. To show how accurately such work can be done, the author would state that for the Jefferson City Bridge he gave his resident engineer instructions to [illegible] no variation from correctness exceeding three-eighths of an inch [illegible] the main triangulation itself or in the intersections for pier [illegible] instructions were followed so faithfully that no error [illegible] sixteenths of an inch was allowed to pass in any part of the [illegible] whole field-force once lost an entire half day in rectify[illegible] one-half of an inch in the intersection for a pier centre. [illegible] cellent record for accuracy, considering that the distance [illegible] lines on the bridge tangent was a little over fifteen [illegible] author is generally not so rigid in his requirements [illegible] was in that case, the reason for such strict instruction[illegible] that it was the resident engineer's first experience in [illegible] lation.

[illegible] baseline, was probably [illegible] City Bridge, because the errors [illegible] measured on top of the falsework were [illegible]

[illegible] of the extreme accuracy with which triangulation [illegible], the author would refer to that for his Fraser River



[illegible] System for the Proposed Bridge over the Entrance Channel [illegible] to Havana Harbor, Cuba.

[illegible]minster, B. C. The said work was done under his [illegible] his resident engineer, H. K. Seltzer, Esq., C.E. [illegible] tangent between the opposite base lines was about [illegible] feet; and it was found practicable to measure base [illegible] of triangulation. Three of the lines were of ample [illegible] was so much shorter than the others that the re[illegible] were finally discarded. As there was a railroad [illegible] river near and approximately parallel to the [illegible] were quite favorable for base line measure[illegible] done in the early morning before sunrise.

The lengths of all base lines were [illegible] curacy that the largest variation from the [illegible] for one side of the river and one part in [illegible] thirty to sixty measurements of each angle were [illegible] closure per triangle was less than one second. [illegible] length of bridge tangent obtained from three triangles was [illegible] ($^7/_{16}$) of an inch, and the greatest possible error was not [illegible] eighths (⅝) of an inch. Although the water at the [illegible] eighty feet deep and the current ran both in and out with velocities [illegible] great as five miles per hour, the piers with their anchor bolts were [illegible] accurately located that it was found impracticable to measure the [illegible] in any span length. Work of such accuracy as this costs money—[illegible] that money generally comes directly out of the consulting engineer's [illegible] pocket; nevertheless on important construction it should never be slighted [illegible] in the least degree, no matter how great may be the expense involved [illegible] doing the triangulation strictly in accordance with the preceding directions.

After the main triangulation for a bridge is finished, the next step [illegible] to compute the angles to the various points on the piers that will be needed [illegible] during the sinking. For a single cylinder pier it will suffice to triangulate [illegible] to the centre only and for a pier composed of two cylinders a triangulation to the centre of each cylinder will be enough; but for a rectangular [illegible] pier it will be necessary to locate not only the centre, but also another [illegible] point near the periphery, in order to prevent the pier from being rotated [illegible] about its vertical axis in going down. After the calculations are completed, a triangulation-sheet should be prepared, on which should be [illegible] shown all of the triangulation with the various distances on all lines and [illegible] the exact angles for all deflections.

Foresights should next be located for the bridge tangent and for all [illegible] pier points, so that the transitman will never be under the necessity of [illegible] turning off an angle when locating a pier. The position for any foresight is generally determined by convenience, but it should be chosen [illegible] as to avoid any probability of disturbance. Each foresight, which consists of a substantial wooden target, is located by turning off the [illegible] angle as nearly exact as may be, putting it firmly and substantially in [illegible] place, and making a provisional mark upon it. Then obtain the approximate distance L from instrument to target by either stadia or [illegible] Next measure accurately by repeating ten times or more the [illegible] tually set off by the provisional mark on the target. The [illegible] between this last angle and the true angle desired, as originally [illegible] will be a very small angle. Call it D and express it in [illegible]

mals of a second. Then the desired correction is equal to [illegible]

same unit as that of L. Finally, set off the correction [illegible] to right or left as may be needed, and the foresight [illegible] will be obtained. Each target is to be marked also [illegible]

its individuality may be recognized by the distant point of observation. All foresights occasionally so as to see that they have not been any disturbance will be discovered, the first time used, by the three lines failing to intersect in a point.

CHAPTER LXI

ENGINEERING OF CONSTRUCTION

No matter with what care and skill a bridge adequately the specifications governing its construction plans are not faithfully carried out, and if the specifications hered to, the result will fail to attain the standard of the designing engineer, and to secure which his client result is not positively bad and dangerous, it is at least a cheat. To forestall such a miscarriage of the client's a heavy responsibility on the consulting engineer who for the structure. This will be better appreciated, ing Chapter LXXVI. Such responsibility makes it protection, as well as for his client's, that he have information that the construction work is being carried with his plans and the spirit of his specifications. As the principal incentive for doing the work is the anticipated often happens that a short-sighted one will endeavor to profit by slighting the work. To meet this and other exigencies during construction, it is customary to have an engineer

This resident engineer should be in the employ of the engineer who prepares the plans. His function, speaking in is to supervise and facilitate the construction work. his duties are about as follows:

1. To locate piers and abutments.
2. To give line, grade, and cut offs.
3. To inspect and test all materials entering into the ture, such as sand, rock, gravel, cement, concrete, and timber.
4. To supervise construction.
5. To check daily the positions of caissons.
6. To make progress reports.
7. To make monthly estimates of work done.

Where a tramway is built out from the shore for con poses, the piers can conveniently be located by direct by running on it an auxiliary working line, parallel, if bridge tangent. Perpendicular lines are then turned intervals for the piers; and the proper offset distances ard the bridge tangent, thus locating the pier centres is danger of the high water carrying out the tram are built to above the water line, a triangulation

[illegible] this work will be found [illegible]
[illegible] lines for construction work, such as [illegible]
[illegible] on an abutment, permanent [illegible]
[illegible] that the instrument-man can recover [illegible]
[illegible] the desired information. Care must be [illegible]
[illegible] and targets are not set too near the field of the
[illegible] for his excavations are very apt to cause [illegible]
[illegible] earth and thereby destroy the reliability
[illegible] placed too close. It is a good plan to advise the
[illegible] a diagram, of the location of these targets and
[illegible] this cooperation in keeping the lines cleared [illegible]
[illegible] Consideration must be given to the fact that as the
[illegible] build up, they will more than likely shut off the
[illegible] it will be necessary to use a back sight instead of
[illegible] in recovering such a line. Concrete monuments about
[illegible] three or four feet deep, set flush with the ground sur-
[illegible] cheaply constructed. A six-inch lag-screw set in the
[illegible] of the concrete top serves to hold the punch mark
[illegible] centre on line. The concrete should slope in all
[illegible] top of the lag screw, which will then serve also as a
[illegible]

[illegible] should be distributed at convenient locations so that
[illegible] given without involving more than one set up, thus
[illegible] reducing the chance for errors creeping in when hurried
[illegible] be made. All locations, measurements, and ele-
[illegible] should be checked several times at the time of
[illegible] and they should further be checked during the
[illegible] if there has been any reason to suspect that the
[illegible] disturbed.

[illegible] materials in the field is only to supplement shop
[illegible] tests and not to supersede them. Metal should
[illegible] time of its unloading to see that it has not been
[illegible] no pieces have been lost in transit. Timber also
[illegible] the time of unloading to see if it conforms with
[illegible] to soundness, freedom from knots and cracks,
[illegible] and proper size, and that the amount delivered
[illegible] Ordinarily it is the Contractor's business to do
[illegible] Resident Engineer should satisfy himself that it is
[illegible] inspected in car at time of delivery for hardness
[illegible] Sand, also, should be similarly inspected.
[illegible] from the bed of the river at or near the
[illegible] inspected for cleanness and tested for per-
[illegible] be used for concrete. The test for voids
[illegible] a platform scale, like those used on store

counters, and a bucket. The bucket is first weighed, then filled with water and weighed again; then by subtracting the weight of the bucket, the net weight of the water is obtained, which, of course, is proportional to its volume. Empty the bucket and fill with gravel and weigh, then fill with water and weigh again. The difference between these last two weights represents the amount of water required to fill the voids. This difference divided by the weight of water filling the bucket alone gives the required percentage of voids. It is frequently possible to decrease the percentage of voids by adding coarser or finer material to the aggregate, and the engineer should experiment in order to determine whether such decrease can be effected; because, generally, the saving of cement thus effected overbalances the slight cost of adding material.

The cement should be sampled and tested after it has arrived on the work. The usual tests to be made in the field are for time of setting, soundness, and tensile strength. These should be conducted in accordance with the specifications of Chapter LXXIX.

It is desirable to have some check on the quality of the concrete being produced as the work progresses. The simplest procedure is to make small beams, say 4″ × 4″ × 26″, and then determine the modulus of rupture by bending tests. The compressive strength may be approximated by the formula,

$$f_c = (8.64 + 1.8 \log_{10} A) f_t.$$

where f_c = compression strength.

A = age of sample in months.

and f_t = tensile strength.

A better check is to take samples of the concrete from the batch as it is being placed and put into cylindrical moulds about 8″ in diameter and 16″ long. These should then be stored so as to be under practically the same conditions of temperature and moisture as the concrete in the work. These cylinders can then be tested from time to time in a compression machine at the nearest laboratory. Cylindrical samples are to be preferred to cubes, because the concrete specimen fails along diagonal planes at about 55 degrees to the horizontal. In the case of cubical specimens, the friction of the specimen on the plate of the testing machine is sufficient to give an apparent higher resistance. This sampling of the actual concrete as it goes into place and its subsequent testing have a wholesome moral effect on the contractor and lead to a more careful mixing and adjusting of the percentage of water, as a material difference can be produced in the strength of the concrete by changing this factor. Again, the knowledge of the actual resistance of the concrete as placed is of value to the designing engineer in guiding him in future work.

According to the specifications given in Chapter LXXIX, the contractor has the privilege of having any of the materials used on the work tested at other places than the site. In that case the resident engineer will send a competent inspector to each point indicated by the contractor,

but the latter must then bear all the expenses of every kind incident to such testing, including the salary, travelling expenses, and board of the special inspector. This privilege is often utilized in the case of cement, piles, timber, crushed rock, and creosoted timber.

In having such testing done at a distance from the bridge site, on account of its special character the engineer assumes a certain moral but, possibly, not a legal obligation to make such inspection final, although the specifications contain a direct statement to the contrary. On this account care should be taken to send only an experienced inspector on such special work, and in most cases the engineer should rely upon his thoroughness and judgment. If he passes a lot of material that is unfit for use in the construction, such inferior material has to be rejected at the bridge site; and immediately there arises the question as to who shall bear the pecuniary loss involved by such rejection. The contractor feels that he should not be called upon to stand it, for he has done all that lies in his power to secure good material, even to the extent of paying for the extra cost of the inspection; the supply man, often chuckling to himself, says, "You accepted the material and that settles the matter as far as I am concerned"; the client says to the engineer, "I don't see why I should be made to bear this useless expenditure—what am I paying you for?" The negligent or culpable inspector is, of course, too impecunious and irresponsible to assume the pecuniary responsibility; and the engineer is not paid a sufficiently large fee to warrant his guaranteeing the client against mistakes of his employees. If the question were brought before a jury, in spite of the specifications providing to the contrary, they would probably saddle the expense onto the client, unless it could be shown that there was fraud involved on the part of either the supply-man or the contractor.

A case of this kind arose lately in the practice of the author's firm. It became necessary to inspect some railroad ties for a large viaduct; and the only man available was a young university graduate of seven years' experience in office and field—an honor man, by the way. He was given a copy of the specifications and some sound, practical advice before starting; but the result was disastrous, for he accepted several car loads of ties, half of which were unfit for use. They were crooked, under-sized, and rotten. The outcome of the matter was that by mutual agreement the loss was to be borne equally by the contractor and the engineers, the former being punished for having dealt with a notoriously tricky supply man and the latter for their failure to select an experienced inspector. This case is quoted as a warning to all resident engineers to be careful in their selection of inspectors for the examination of materials at places other than the bridge site.

The author at various times has had occasion to inspect for his work great amounts of timber, some single orders involving as much as ten or twelve million feet board measure, and he has almost invariably had

[illegible]

[illegible] from [illegible] the timber was to be cut or [illegible] that sizes of them for inspection is that [illegible] inferior material; hence one should first [illegible] the reputation for honesty of such inspectors [illegible] in testing cement at the manufactory the [illegible] self against the possibility of the [illegible] cement than that which he has had inspected and [illegible] impossible to mark all the bags, and generally [illegible] before bagging; hence the only truly safe [illegible] spector at the mill until the last of the [illegible]

When inspecting broken stone at the crusher, [illegible] after are the freedom of the product from dirt, [illegible] of no unsuitable stone, and the adherence to [illegible] size. In some localities it seems almost [illegible] stone, even where good rock is plentiful; [illegible] rocks sent to the crusher are liable to become [illegible] clay. This is very difficult to remove, and its [illegible] are bad, notwithstanding all that may be claimed [illegible] cause when little lumps of clay become mixed in [illegible] small surfaces where the strength is but little [illegible] clay were thoroughly dry and mixed uniformly [illegible] that would be an entirely different condition; and [illegible] an increased strength in the concrete. It is, therefore, [illegible] resident engineer pay special attention to the [illegible] his concrete; and any inspector whom he sends to [illegible] stone at the crusher should be one whom nature has [illegible] back-bone.

The supervision of construction means seeing [illegible] specifications and plans are being carried out. [illegible] neer is called upon to exercise good judgment and [illegible] distinguish between those operations which directly [illegible] of the structure and those which are incidental and [illegible] major operations. For example, the location of a [illegible] of a pile driver are of the incidental order, but the [illegible] crete deposited by that derrick or the position and [illegible] pile driven by the pile driver are of the major order [illegible] to the satisfaction of the engineer as defined by the [illegible]

While the engineer may very properly make [illegible] cidental operations, especially if called upon to do [illegible] it is better policy to refrain from giving unsought [illegible] contractor manage his own business as far as [illegible] out the plans and specifications. It should be [illegible]

on him. He should
that his compensation covers the
should be said or done by the
as a shifting or a dividing of this
anticipated operations of the contractor would
with the engineer's instrumental work or would
rapid progress of the construction, the engi
advise or remonstrate, and even in extreme cases
power should be used with great discretion and

be built in open coffer dams, the work of locating
simple, for when they are once located little or
place afterward. But when piers are to be sunk by
or by open dredging, great care must be taken
the pier is always either moving or liable to move
sinking piers by either of the two last-mentioned
engineer should keep such notes that from them
to the exact horizontal position of the cutting edge
position of the top of the pier, the elevation of the
inclination of the axis of the pier to the vertical, and
that the pier has been revolved around its vertical
can conduct his operations with much more cer-
pier in its true position, if he be kept informed as
every day.

staging be used around the pier, from which to conduct
construction, keeping track of the various motions of
comparatively easy task, for the approximate alignment
temporary points located on the staging, which
occasional checking to see that the said staging
ly. If there be no staging, all locations will have
ulation, and, as before stated, two points on each
in order to detect rotation. When the caisson has
depth, however the liability to rotate is greatly
that may be said, the work of keeping the pier in
dependent on local conditions and many varying

care should always be taken to preserve such
enable the leveller to keep a record of the vertical
edge to the top of the crib at each of the four
necessary in order to determine how much the
level.

tions for the copings of the piers, it will some-
take very long foresights, owing to the im-

practicability of setting up the level near the [illegible] sight should be taken to a bench-mark about [illegible] instrument as the pier is therefrom, and in the [illegible] to effect a possible slight lack of adjustment in the [illegible] for the curvature of the earth.

The method of finding the variation from correct [illegible] top and bottom of a caisson during the process of sinking [illegible] aration of the data required by the contractor for [illegible] are somewhat complicated, consequently the said method [illegible] appended. The manner in which it was evolved some [illegible] years [illegible] by the author was rather amusing. Up to that time he had left to [illegible] resident engineers the task of finding by methods of their own the de[illegible] positions of cribs and caissons; but once when visiting a bridge [illegible] construction he found that the engineer in charge was unable to [illegible] the problem. The engineer demanded formulæ and showed several [illegible] successful attempts of his own to obtain them, consisting of a complicat[illegible] mess of sines, cosines, and tangents involving inextricable confusion [illegible] reaching no result. The author sat down and prepared the follow[illegible] demonstration, which he submitted to the resident engineer to [illegible] All went well till the point was reached where the assumption is [illegible] that two lines are parallel when they are not. The young man [illegible] "Here, this is all wrong; because those lines might be far from paral[illegible] and the formula would be totally incorrect!" The reply was, "If the[illegible] is any serious incorrectness, you are at fault for having permitted [illegible] caisson to get so much out of position; but even if there is a great [illegible] involved, the first sinking, if properly managed, will render it [illegible] able." It was difficult to convince the young man, who had [illegible] away from the technical school long enough to lose his [illegible] matical formulæ, that the method was proper, but after he had [illegible] a few times he became firmly convinced of its usefulness and [illegible] factory character. Every since then it has been a part of the [illegible] of the author's field engineers.

METHOD OF LOCATING THE POSITION OF A CAISSON DURING SINKING

N. B. The subscripts generally indicate a direction [illegible] the plane corresponding to the letter of the subscript.

In Fig. 61*a*, showing a top view of the caisson, let [illegible] two coordinate vertical planes, the former on the bridge [illegible] latter at right angles thereto and containing the [illegible] axis $B\,A\,C$ of the caisson; *i. e.*, the vertical axis of [illegible] passes through the point A. D, E, F, and G are the [illegible] the four corners of the crib or caisson. Let the [illegible] angle of the crib at any time during sinking be [illegible]

letters, and that of the bottom at the same time by the letters marked seconds.

The fieldwork consists of the running in of the lines XX and YY, finding their intersections with the edges of the crib, thus locating the points B' and C' and determining their distances from the coordinate axes, and taking levels of top of crib at the four corners.

It is understood that the vertical distances from bottom to top at the four corners have been measured, marked on the timber, and recorded in the note-book, so that if the top surface of the crib is not truly parallel to the bottom surface of the caisson the elevations of the four corners at the top can be corrected accordingly so as to make the two planes parallel.

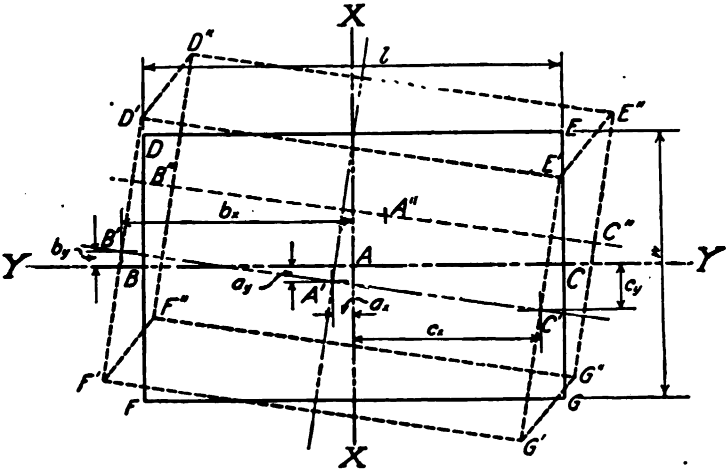


FIG. 61a. Position of Caisson During Sinking.

Let b_x = perpendicular distance of B' from XX.
Let c_x = perpendicular distance of C' from XX.
Let a_x = perpendicular distance of A' from XX.
Let b_y = perpendicular distance of B' from YY.
Let c_y = perpendicular distance of C' from YY.
Let a_y = perpendicular distance of A' from YY.
Let h = height from bottom of caisson to top of crib.
Let l = length of crib (FG or DE).
Let w = width of crib (DF or EG).
Let e_d = corrected elevation of corner D'
Let e_e = corrected elevation of corner E'.
Let e_f = corrected elevation of corner F'.
Let e_g = corrected elevation of corner G'.
Let e_m = mean of e_d, e_e, e_f, and e_g.

[illegible]

$$a_x = \tfrac{1}{2}\,(c_x$$ [illegible]

[illegible]

$$b_y + a_y =$$ [illegible]

[illegible]

$$a_y = \tfrac{1}{2}\,(c_y$$ [illegible]

Equations 1 and 2 locate the position of the [illegible] to the coordinate planes.

The amount that any properly vertical line in [illegible] $D'F'$, $D''F''$, or $E'G'$, $E''G''$, or in any parallel plane [illegible] is out of position in said plane between top and [illegible] zontally is

$$(e_f - e_d)\,\frac{h}{w} \quad \text{or} \quad (e_g - e_e)\,\frac{h}{w}$$

But as the lines $D'F'$ and $E'G'$ are very slightly [illegible] plane XX, no error of consequence will be involved [illegible] this variation is parallel to XX, therefore the distance [illegible] between the projections of A' and A'' on any horizontal [illegible]

$$x = (e_f - e_d)\,\frac{h}{w} = (e_g - e_e)\,\frac{h}{w}$$

Similarly the distance parallel to YY between the projections [illegible] and A'' on any horizontal plane is

$$y = (e_d - e_e)\,\frac{h}{l} = (e_f - e_g)\,\frac{h}{l}$$

The coordinates of A'' in relation to XX and YY will [illegible]

$$X'' = a_y \pm x$$
$$Y'' = a_x \pm y$$

The corrected heights of the four corners above and below [illegible] mean plane are respectively.

$$v_d = e_d - e_m$$
$$v_e = e_e - e_m$$
$$v_f = e_f - e_m$$
$$v_g = e_g - e_m$$

The amount that the crib has been rotated about [illegible] measured by the sine of the angle of inclination (θ) [illegible] the line $D\,E$, or

$$\text{Sine } \theta = (c_y - a_y) \div \frac{l}{2}$$

The data to be given daily to the contractor are as follows:

1° How much too far North or South the point A' is.

2° How much too far East or West the point A' is.

3° How much too far North or South the point A'' is.

4° How much too far East or West the point A'' is.

5° How much each of the four corners is high or low above mean plane.

6° How much the crib is rotated about its vertical axis, and in which direction is the rotation.

This information is given respectively by Equations 1, 2, 5, 6, 7, 8, 9, 10, and 11.

In case that the points B' and C' both lie on the same side of YY, the sign of b_y in Equation 2 would, of course, have to be changed, making that equation

$$a_y = \tfrac{1}{2}(c_y + b_y)$$

In applying Equations 5 and 6, care will have to be used in regard to the signs; but it is easy to see in any case whether the terms are additive or subtractive.

The contractor should be instructed to use the engineer's height-marks at the corners when correcting the position of the crib instead of measuring from the corners of the timber or metal as actually built.

Records and Reports

The business of making records, reports, and estimates is a most important one for the resident engineer. To systematize such work and produce a uniformity of results, the author's firm has prepared a complete and detailed set of instructions for its resident engineers, from which the following is quoted:

Records and reports are for information, the latter for the present information of the Main Office, and the former for the present use of the Resident Engineer and for the ultimate information of the Main Office Records. They should be legible, concise, and comprehensive—permanent, accurate, and intelligible. This requires orderly, systematic arrangement. Blanks for records and reports will be furnished from the Main Office.

(*a*) *Records.*

The Following Records Are To Be Kept

1. Records of Progress of Work.
2. Daily Record of Work.
3. Material Record.

4. Field Notes.

5. Correspondence.

6. Estimates { **Monthly.** / **Final.**

7. Expense Accounts (Monthly).

8. Unclassified Work Accounts.

9. Final Quantities.

10. Employment Records.

1. *Records of Progress of Work.*

Records of the progress of the work shall be neering Staff Reports, amplified where necessary by copy of each report as hereafter specified to be by filing other reports; and by the records

2. *Daily Record of Work.*

The daily record of work will be given by the port, amplified by attached notes where necessary. work where one man does all the inspection and may be kept in a bound diary similar to Diary No. the Excelsior Diary Co. For all work where more ployed, the daily record is to consist of a series of with McGill fasteners on card backs, or to be filed box, one leaf to be made out, numbered, dated, and ployee. These are to be received by the Resident than the following morning, to be checked, countersigned, own card is to accompany the others and give a general entire work.

SAMPLE

WADDELL & HARRINGTON

ENGINEERING STAFF REPORT

Job: Little River Bridge

The following work was done today under my supervision:

12 men concreting base Pier 2,
used 300 sacks cement—about
60 yds. of concrete. Delayed
one hour for cement.
Gave elevations for top of concrete of base.

O.K.
M.J.M

Cloudy.
My time 10 hrs.

“Daily Records” are to be made *daily* and are ink. They are to include by each man, for the a general epitome of the disposition of the ment, with approximate quantities, of what has

such items of conditions for work, weather, and of especial moment which are of interest. Where instrument work or other engineering work has been done, a statement of what has been accomplished is to be given.

If mixing and laying concrete, there must be stated the number of yards mixed and the number of barrels of cement used. (This latter item will be gotten from the Contractor's office or from the man keeping count of barrels.) If driving piles, there must be noted the number of piles driven and the approximate penetration for all piles.

If the bridge is not in or near a town, and the contractor has to maintain a camp for the boarding of the men, the Engineering Staff shall make arrangements to board with the contractor, unless there is some place in the vicinity where board can be obtained. In any event, where the work is away from a town or city so that the Engineer's staff can be in office after working hours, the daily, weekly, and all other reports can be made out then; but if the work is in a town or city, the crew will become scattered after working hours. In that case each man must turn in his report promptly at 7 A.M. of the morning after the day which the report covers, so that the Resident Engineer or his assistant can mail his daily report not later than noon. If this is carried out, the matter of getting up the reports will take a very small amount of time each morning.

If orders for special work or special instructions to Contractor have been given, note should be made thereof for the order. Give details in figures or approximate figures; for instance, do not say: "Piles we have been waiting for came in," but say: "50 piles in today, have been waiting for them since May 20th."

3. *Material Record.*

A record of materials received is to be kept in a bound book, and entries are to be made not later than the day after the material is unloaded.

The Contractor is to be requested to furnish this daily information in suitable memoranda; and he may be advised that the make-up of his monthly estimate will depend on the promptness and accuracy of his information. Car numbers and shipment numbers are to be given. Materials delivered by wagon, boat, or raft are to be so noted.

The daily record sheets are to contain sufficient information to check approximately the Contractor's data.

It Is Not the Duty of the Engineer to Check or Receive Material.

He is in no way responsible for materials or their storage.

The Engineer shall not make out detail bills of materials or in any way assume responsibility for the amounts ordered. He shall, however, determine in a general way the times that various materials should be received and shall remind the Contractor of his needs.

The Contractor shall be required to furnish likewise daily a memorandum, giving the number of men and foremen working each day and the disposition of forces. Details of time and payment are not desired but merely the number of men.

In case the Purchaser furnish certain materials, he shall furnish also a material man to receive and receipt for such materials. This is not the Engineer's duty. If the Purchaser has no staff on the ground the Resident Engineer will employ a suitable man whose salary, together with all expense involved in looking after the Purchaser's material, shall be paid by the Purchaser, usually through the Contractor under Unclassified Work.

4. *Field Notes.*—(We recommend Dietzgen Books—Field Book 400: Level Book 410.)

Full and definite field notes are to be made of all surveys and measurements. They should be complete in every detail and prepared in a neat and legible manner. Notes and sketches should be clearly made with a hard pencil so that they will not become blurred.

An office field book is to be kept in the office and not taken on the work; and into this are to be copied the notes from the field books used in the field. This copying may be avoided by the use of loose-leaf notebooks, the sheets of notes being merely transferred to the office book. Such notes as are needed again in the field, as, for instance, distances or bench marks, may be copied, as required, from the office book.

In using the loose-leaf system, each leaf should bear the date of work and the name of the compiler so as to be complete in itself.

When corrections or additions are made to field notes after they are placed in the office, they should be in ink or colored pencil over the signature of the corrector and with date of correction given. No erasures in field notes are permissible. Erroneous work is to be crossed out and correct work given near by.

The details of handling field notes will be left as much as possible to the preference of the Resident Engineer, but the following must be included. Each book is to be indexed, the indexing being done as the notes are put in the book. Each book is to have a title in ink on the first inside page, giving the name of the Engineer and a page or so of information about its contents. There have been numerous books turned into this office without title or name or marks to tell to what the notes apply. It is well to explain in preface-remarks that certain notes are preliminary or merely approximate, and to designate fully those which are final.

Title and index every book of an entire series, for although you may send them in tied together, they are likely to become scattered.

The value and character of field notes are determined by the ease with which any one, other than the maker, can follow them through and understand what was done.

A change of personnel may be made at any time, and the notes should be in such condition that the incoming engineer may have decipherable information. Especially is it necessary to give full explanation of preliminary survey notes, such as hydrographic maps.

Book No. [illegible] is to be used for making records
construction a sketch of the pile plan should
the piles should be numbered. Columns
Pier No., Pile No., Length delivered, Length put in
Time Started, Time Finished, Elevation of Top
Bottom, length below cut-off or below base of pier,
blows, Drop of Hammer, Weight of Hammer,

Sinking.

Sinking are to be kept on special sheets, and are
there is provided a continuous record for each pier.
sent to the Main Office except in cases of special diffi-

the progress of work, data are sent to the Main Office
special parts, etc., the notes are to be reduced to profiles
of the original field data are also to be sent in so
may be verified.

copies, or preferably both, are to be taken
by the Resident Engineer. All correspondence must
together in order, and complete files are to be sent
when the job is finished. All formal written instruc-
Contractor are to be handled as correspondence. Roll
requiring no copying press.
date ——" on all letters and papers coming to
important in the case of blue-print plans, etc.
prints are sent out and these should be substituted
immediately and without fail. The old prints
" in evident manner, and then filed away till
after final settlement they should be destroyed.
job the blue-prints are to be destroyed, except those
" as hereafter noted.

be devoted to the preparation of monthly estimates
included therein. These notes need be only rough
be put in the book so they can be referred to.
by allowing the Contractor a certain value for
and certain fixed prices for quantities of work
material used in that work is deducted from

the total allowable value of the said work and [illegible] the Contractor.

The specifications read: "On or about the [illegible] Engineer shall prepare accurate estimates of the [illegible] nished and work done to date." Thus there is some [illegible] what day the estimate runs up to—presumably, [illegible] but it may be to the 27th or the 28th or to the 3d or [illegible] The estimate forms are made so that each monthly estimate [illegible] statement of the work from the beginning, and, except for the statement of money already paid the Contractor, is entirely independent of every other estimate.

Each estimate can, therefore, be made by adding the increments for the current month to the sums previously given, or by making independent figures; thus permitting a possible inaccuracy to be easily corrected.

All items payable under the contract are to be included in the estimate sheet, so that the entire accounts may be kept clear. This applies to such items as extras, bonuses, lump sums, etc.

(a) *Value of Material Furnished.*

Usually in the contract there will be fixed schedule rates, to be used in valuing materials furnished; but if these are not given, the Resident Engineer should investigate the cost of the materials delivered and unloaded and fix equitable rates. A close approximation will suffice, [illegible] these figures are merely payments on account, and they all [illegible] the final estimate.

If the material record is complete, the quantities [illegible] bined with the rates so fixed determine the value of the [illegible] ered at site. If the material record is incomplete, it is [illegible] ure the amounts of all material on hand, including that [illegible] placed in permanent position, and that which has not yet [illegible]

Under the items on the Estimate Sheet of the various [illegible] livered at site give the quantity, rate, and value.

(b) *Value of Work Done.*

In the contract there are given unit price values for [illegible] of completed quantities. The value of the work done will [illegible] of the completed item less the value of the material. [illegible] timber delivered at site is worth $20 per thousand, and [illegible] is worth $35 per thousand, the value of the work done is [illegible] This is so arranged on the estimate sheet.

Under the items of various final quantities place the [illegible] pleted to date, as ——— cubic yards of concrete, [illegible] piles in place, etc., the contract unit price, and the result[illegible] under the column marked "Previously Estimated" [illegible] the value of the raw materials used in the completed [illegible] prices at which you valued them delivered. The [illegible] forward to the last column and represents the value [illegible]

WADDELL & HARRINGTON,
CONSULTING ENGINEERS,
KANSAS CITY, MO.

For

Ft. Smith Van Buren District,
Ft. Smith, Arkansas.

Contract No. 1
Estimate No. 5

Estimate of Work Done by Kahmann & McMurray. During Month of March, 1911.
On Substructure—Ft. Smith-Van Buren Free Bridge.

Items	Total Aggregate of Work Done and Material Furnished to Date	Schedule Price	Total Aggregate of Value to Date	Previously Estimated on This Sheet	Difference	Remarks	
Metal delivered at site....	100000 lbs.	$0.035	$3500.00	....	$3500.00		
Metal erected............	71700 lbs.	0.045	3226.50	$2509.50	717.00	71700 at .035 =	$2509.50
Caisson timber delivered...	900 M	20.00	18000.00	....	18000.00		
Caisson timber in place....	530 M	30.00	15900.00	10600.00	5300.00	530 at $20.00 =	10600.00
Sand delivered at site.....	6000 c. y.	0.75	4500.00	....	4500.00	Stone 550 c.y. at $1.00 =	550.00
Broken stone del. at site...	7850 c. y.	1.00	7850.00	....	7850.00	Sand 300 c.y. at 0.75 =	225.00
Cement delivered at site...	9500 bbl.	2.00	19000.00	....	19000.00	Cement 720 bbl. at 2.00 =	1440.00
							$2215.00
Concrete in abutments....	600 c. y.	11.50	6900.00	2215.00	4685.00	Stone 3000 yd. at $1.00 =	$3000.00
Concrete in shafts of piers..	3340 c. y.	9.00	30060.00	12252.50	17807.50	Sand 1670 yd. at 0.75 =	1252.50
Mass of foundations.......	4725 c. y.	18.50	87412.50	26900.00	60512.50	Cement 4000 bbl. at 2.00 =	8000.00
							$12252.50
Piles delivered at site......	3770	0.10	377.00	....	377.00		
Piles in place.............	980	0.50	490.00	98.00	392.00	Stone 3200 yd. at $1.00 =	$3200.00
Extra bills previously rend.	....	....	835.25	....	835.25	Sand 1600 yd. at 0.75 =	1200.00
						Cement 4200 bbl. at 2.00 =	8400.00
Extra bills No. 3 attached..	....	....	88.85	....	88.85	Timber 470 M at 30.00 =	14100.00
Extra bills No. 4 attached..	....	....	250.81	....	250.81		$26900.00
			$198390.91	$54575.00			
		Total Amount of Estimate to Date......			$143815.91		
		Ten per Cent Reservation..............			14381.59		
		Net Amount of this Estimate...........			$129434.32		
		Previous net estimate Feb. 1, 1911.......			84652.38		
		Amount Payable........................			$44781.94		

We certify this estimate is correct.
WADDELL & HARRINGTON,
Consulting Engineers.
Per F. M. Cortelyou,
Resident Engineer.

FIG. 61*b*. Monthly Estimate Sheet.

[illegible] completed item. [illegible] is to be deducted the value of the [illegible] Likewise Mass of Foundation in place [illegible] consists of concrete and timber, hence [illegible] Mass of Foundation in place is to be deducted [illegible] concrete and of the timber in place composing [illegible]

([illegible]) *Bills of Unclassified Work.*

All bills due on account of work done on any [illegible] vision for payment is not made in the contract are to be [illegible] the form shown in Fig. 61j. Such items are to be [illegible] classified Work.”

The Contractor is to make out the bills on these [illegible] as many copies as desired. He should, of course, [illegible] to the Resident Engineer the details of the bills and have [illegible] condition before rendering.

Where the letter ordering the work is long or involved, or the work lasts over a number of months, it may be pasted to the [illegible] When possible it is better to copy the letter each time.

Detailed payrolls and material bills are to be [illegible] Harrington, Main Office, for file.

Bills for Unclassified Work are to be cleaned up each month, and all such work is to be included on the monthly estimate. [illegible] should be advised that all bills for Unclassified Work [illegible] promptly month by month, if they are to receive consideration.

Unless special orders are given, there are to be five [illegible] timate made. Four of these are to be sent to the office, [illegible] checked they will be forwarded.

One copy is to be retained by the Resident Engineer.
One copy is for the Office.
One copy is for the Contractor.
Two copies are for the company.

The usual items given by the estimate will be as follows:

Superstructure under Different Classifications.

Riveted Truss Spans
Pin-connected truss spans.
Lift Span.
Towers.
Girders, etc.
    Metal delivered at site.
    Metal erected.
    Metal riveted.
    Metal painted and completed.

[illegible]

[illegible] delivered at site.
[illegible] in place.
[illegible]
[illegible] at site.
[illegible]
[illegible] at site.
[illegible]
[illegible] ally no allowance is made for falsework.)

[illegible] delivered at site.
[illegible]
[illegible] on hand.

[illegible] lumber delivered at site.
[illegible] lumber in place.

[illegible] at site.
[illegible] stone delivered at site.
[illegible] delivered at site.
[illegible] ing metal delivered at site.
[illegible]
[illegible] in ——.
[illegible] in ——.
[illegible] in ——.

[illegible] Foundations in place.
[illegible] Piers in place.

[illegible] Piles delivered at site.
[illegible] Piles in place.

[illegible] Bills previously rendered.
[illegible] Bills attached.

[illegible]

[illegible] will contain the exact final quantities of the vari- [illegible] for in the contract; but as in most cases all raw [illegible] will have been incorporated into the items for payment, [illegible] materials delivered are omitted entirely.

[illegible] apply on any estimate. When all of a given raw [illegible] ated into items of final quantities, its valuation [illegible] may be dropped. For instance, after all the con- [illegible] be valued at contract price and no deduction made [illegible] terials, and no mention need be made of valua- [illegible] delivered. This is to be applied only as the

items of the contract are completely
though the amount of a material delivered
are identical.

As all the estimates except the final are for
is not necessary to carry out the figures of
They should be so figured and recorded in the
nearest even figure may be given on the estimate,
uring and checking. For instance, if there have
1,287.2 cu. yds. of stone, the figure may be given as
cu. yds. without impropriety. Final quantity figures
be given exactly after having been carefully computed

8. *Unclassified Work.*

The specifications are so written as to include every
it seems will be needed to complete the entire
classified or included under the classifications given
written order, which written order must be delivered
by the Resident Engineer before the work is done.
classified Work will be sent from the Main Office to the
must pass through the hands of the Resident Engineer
in making up the estimate.

Extra claims advanced by the Contractor after the
not be allowed.

The Resident Engineer will keep accurate accounts of
expenses for materials; and as all such orders are to
fore any work is done, he is in a position to know
has been ordered and how much should be allowed.
men must be watched with sufficient alertness to see
their entire time to the duties assigned. Under
will not be necessary to employ a special man to keep
material used in doing Unclassified Work; but the
such work shall keep a record of the amount of labor and

Inspectors keeping such records should compare the
charged to Unclassified Work with the Contractor's
must be done daily, as by so doing disputes will be avoided.
must report daily to the Resident Engineer's office
employed on all such work so that the Resident
check on the bills when rendered. The Inspector
and turn it into the Resident Engineer daily so that it
with the Contractor's daily report. Where the unclassified
work is of some magnitude and promises to last
demands an undue amount of the time of the
timekeeper or inspector is to be employed; but he
Purchaser on the *Bills of the Contractor*.

Before giving any order for unclassified work,
should consult the Main Office. No extra work

contract to find if the work in question has
, or at least understood and implied to be cov
In case of emergency, if the Resident Engineer is
to take, he may so express himself to the Con-
he will keep account of time and cost to be used
allowed as an extra after consultation with the Main

in mind that the intent of the specifications and
a finished structure, and that all incidental work
are implied. Contractors will often claim prepos-
idea that, if they are allowed, the Contractor is
For instance, in the case of a pneumatic pier a Con-
extra for sealing the cutting edge of the working cham-
such a pier could not be constructed without seal-
any more than it could be without driving nails.
to be paid covered a finished pier ready for use, and
cutting edge sealed.

Quantities.

Engineer is to prepare a book giving final dimensions
all constructions. This book should include nothing
only final figures. Little sketches giving dimen-
if these are so complicated as to require undue time,
plan may be pasted in the book and the final dimen-
"Final." Accompanying the sketches or drawings
calculations for final quantities.
throwing light on the construction is appreciated.
of starting and finishing, highest water, rate of sink-
erection, etc.
include everything of interest to one looking over the
and have it all in the one book so that the com-
the whole construction may be found together and

be marked "Final Quantities for ——— Bridge";
notes that are needed are to be given fully. This
that no other notes need be referred to in order
sizes and position of each part of the structure.

Daily Reports

are to be prepared daily.

on Substructure.

is to fill in every day the columns that are
on the blank furnished for that purpose (see
all piers sunk by either the pneumatic or the
to make daily observations of position and

is to record the same, together with certain other information, on the special blank form provided. (See Fig. 61*d*.) These reports are to be sent every night to the home office.

2. *Daily Progress Reports on Cement Tests.*

Whenever any special tests on cement are being made at any other place than the bridge site, the Inspector in charge of the tests is to make a daily report to the Resident Engineer, using the form shown in Fig. 61*e*.

3. *Daily Progress Reports on Superstructure.*

The Resident Engineer is to fill in every day the columns that are marked with an asterisk on the form furnished for that purpose. (See Fig. 61*f*.) This report is to be sent each night to the home office.

4. *Daily Progress Reports on Reinforced Concrete Structures.*

The Resident Engineer is to fill in every day the columns marked by an asterisk on the blank provided for the purpose (see Fig. 61*g*), and is to send the same each night to the home office.

Weekly Reports

The following reports are to be sent to the office each week, preferably being mailed Saturday night.

1. *Percentage Report of Work.*

This report is general and can be applied to substructure, to substructure and erection, or to erection alone, or it can be used for reinforced concrete structures. The information is intended to be approximate only, and the object of the report is to give the general conditions of the work at a glance. (The form to be used is shown in Fig. 61*h*.)

Under materials, the approximate percentage of each material received is to be shown by one color or by hatching, and the percentage of the material used is to be shown by another color, or in black. On the blank lines materials not mentioned may be included. The amount of each material available is thus readily seen. On the table of "Percentages of Work Completed" several different parts of the work can be shown, each by a separate line; and one line should be given for the contract as a whole. A straight line should be drawn from 0 per cent at date of starting to 100 per cent at date of completion for the job as a whole. Each week only the parts of the lines for that week need be drawn—the prior parts of lines will be filled in by the office. Each line should be labeled or referred to the labels below. It will be noticed that the months are considered as of four weeks each, and such rough approximation will be sufficient for this report.

2. *Weekly Chart of Progress.*

This report is made by marking with colored pencils the condition of

work on a small drawing of the general layout, as indicated on sample. (No illustration is herein given.)

It is desired that these weekly reports reach the office promptly; for copies are sent out to the client and to the Contractor from the Main Office. General notes in a sentence or two should be written on the chart to amplify the information there given.

Monthly Estimates

The monthly estimates are to be made out as described above, and, unless otherwise directed, all copies but one are to be sent to the Main Office, from which they are distributed.

Cement Reports

Reports on the testing of cement are to be made on the Cement Report Sheets marked CR1. (See Fig. 61*e*.) These are made to include tests of two samples. These reports are to be filed in the office of the Resident Engineer; and on the completion of all tests for a given car or bin or shipment, summarized reports are to be made on sheets marked CR2. (See Fig. 61*i*.) A copy of this summarized report is to be sent to the Main Office.

When the tests of fineness and soundness for any given car are completed the Contractor should be notified by letter, thus: "Preliminary tests on Car No. ——— are good," or "show doubtful and will be repeated." When the seven-day tests are completed, give the final word notifying the Contractor by letter advising that Car No. ——— "has been tested and found satisfactory and is hereby accepted"; or if rejected so state, and add "Please arrange for immediate removal."

Report on Materials

In general there will be no regular reports for inspection of material other than cement and steel. Usually where lumber, stone, sand, and similar materials are examined, no report need be made, the advices that such materials are received and unloaded being construed to mean that they have been examined and accepted. For certain cases, such as lumber to be creosoted, notations on the shipping invoices are sufficient. For special cases application may be made to the Main Office, and special blanks will be furnished.

Unclassified Work Reports

All unclassified work is to be reported upon from time to time in sections, as the said work is partially completed, using the form shown in Fig. 61*j*.

Reports on Cost Contracts

Whenever work is done according to the "Cost-Plus-Percentage" or the "Cost-Plus-Lump-Sum" method, the monthly statements are to be made out on the form shown in Fig. 61*k*.

Special

Whenever special reports are made, they
and sent to the Main Office, a copy being
Any special work, such as experiments or
ing special details, are to be reported in full, so that
complete of the findings and conclusions.

Report on Plant

After the Contractor has assembled his plant
with work, make out a Special Report on Plant.
ment of plant on hand, and whether, in your opinion,
be any delay in the progress of any portion of the
absence of any plant or equipment. State the
such plant is not installed, where it is at present,
to have it on the ground.

State the type of each pile driver used, the weight
the length of the leads. Give the type and capacity
mixer and stone crusher on the ground. For jetting
of pumps, size of suction and discharge, capacity of
of water is available and at what pressure it can be
State the number of compressors used and the size
pressure under which these work, the corresponding
number and size of receivers, and the type and size of
of the working shaft. Give number and capacities
Give number and location of derricks. Give a list of
peel buckets, trémies, concrete buckets, etc.

Practically all of the above information will be furnished
tractor on request.

When new plant is provided, a supplemental report is to be

The equipment usually provided for the Resident
the following:

List of Material for Field and Office

1 Transit
1 Level
2 Steel Pickets $3/8''$
1 Level Rod
2 Steel Tapes
1 Metallic Tape
1 Extra Plumb Bob and Line
1 Hand Axe
1 Chopping Axe
1 Box of Tacks
1 Level Book
1 Transit Book
6 Small Note Books

1 Cash Book
1 Letter Copying
Blueprints of
Blueprints of
Copy of Specifications
Estimate Sheets
Contract Prices
Writing Paper
Large Envelopes
Small Envelopes
Pens and
Black Ink
Red Ink

If Cement Is To Be Tested at Site

1 Testing Machine
1 Nest of Sieves
1 Small Balance Scale
1 doz. Moulds
½ doz. Panes of Glass 6″ × 8″
1 Heavy Pane of Glass 13″ × 13″
1 Graduate
1 Coal Oil Lamp
½ doz. Galvanized Tin Pans
1 Cement Record Book
1 Office Lamp
1 Boiling Outfit
1 Damp-box

If Measurements Are Made by Triangulation

2 Wooden Picket Rods
1 Hand Saw
2 Small Brushes
1 Can of White Paint
1 Can of Venetian Red Paint
50 Pieces Tin 1″ × 2″
1 Thermometer
1 Spring Balance
1 Centre Punch

It is hoped that the blank forms given in this chapter, which have been evolved by the author and his firms during the last three decades, will prove useful to the engineering profession, as they represent the result of wide experience and much hard thought and labor. The one given in Fig. 61*b* for the Monthly Estimate Sheet was prepared in its present form by the author himself in 1889 for the Sioux City Bridge over the Missouri River. He has employed it ever since; for he can see no way in which it can be improved. In each case it gives a quantitative history of the entire construction up to date.

It has not been considered necessary to furnish an example of the graphic method of recording the progress of construction, because a simple explanation of its use is all that is needed. The *modus operandi* of employing it, as indicated in the preceding "Instructions for Field Engineers," consists in showing with different colored pencils on certain lithographed sheets containing the general plan and profile of the structure (which sheets, at the inception of the field work, are furnished in ample numbers to the Resident Engineer by the Main Office), the different classes of work done to date, each class being represented by a special color. This method is very effective, because it indicates at a glance the total progress of the entire work in all its details for the different dates when the records were made.

The manner of using these various forms is so simple and obvious as to require no explanation.

In concluding this chapter it is well to state, for the benefit of the younger members of the engineering profession, that the Resident Engineer should never for a moment forget that his employers, the Consulting Engineers, when placing him in charge of the work of construction, entrusted to his care their professional reputation, the most valuable of all their worldly possessions; and that he should always so conduct himself as never to give cause for any one to attack it on account of any legitimate or tenable reason.

[illegible]

[illegible] by this blank neatly [illegible]

Resident Engineer, fill in [illegible]

WADDELL & HARRINGTON
CONSULTING ENGINEERS
Kansas City, Mo.

DAILY PROGRESS REPORT ON SUB

Name of Structure..............

Quantities	Total Estimated	In Place Last Report	Placed Today*	[illegible]	[illegible]
Timber in caissons and cribs					
Concrete in pier bases					
Concrete in pier shafts					
Concrete in pedestals					
Concrete in					
Metal in					
Embankments					

Materials	Amount Required	Total Used	Used Today*	Left on Hand*	Remarks*
Caisson and crib timbers					
Cement					
Sand					
Stone					
Piles					

Fig. 61c—*Continued*

DAILY PROGRESS REPORT SHEET ON SUBSTRUCTURE

Note—Figures on this sheet merely approximate. Sheet No. 4

Resident Engineer, fill in columns marked *

FOUNDATION EXCAVATIONS AND PIER SINKING

River Piers—Nos.	1	2	3	4	5	6	7	Work in Progress Today*
Final elevation, cutting edge								
Settled today *								
Elevation today *								
Land Excavations at								
Total excavation required*								
Total last report								
Excavated today *								

CONTRACTOR'S FORCE*			ENGINEERING STAFF*		
No. Men	Plant	Worked at	Name	Hours	Worked at
	Supts., Clerks, Watchmen, etc.,				
	Total Men				

Resident Engineer

Fig. [illegible]

Pier Location Report

WADDELL & HARRINGTON
CONSULTING ENGINEERS
KANSAS CITY, MO.

PIER LOCATION REPORT

Name of Structure....................................

Pier No........... Date............. Time Record Made

Probable Final Elevation Cutting Edge........

Average Elevation Cutting Edge To-day.......

Average Elevation Cutting Edge Last Report...

Settlement in.........Hours...........Feet

Distance Still to go......................Feet

Elevation Water Surface....................

Elevation Ground Line......................

Immersion..................................

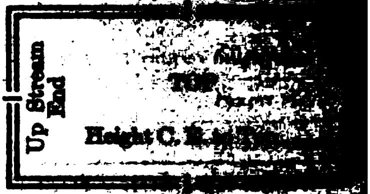
Penetration................................

Air Pressure on Compressor Gauge...........

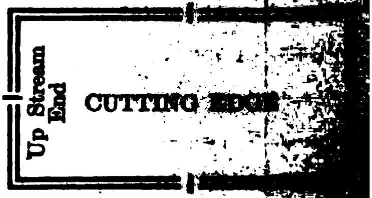
Method of Excavation.......................

....

....



Elevation of Lowest Corner



Concrete Placed Since Last Report..........

Timber Placed Since Last Report............

Elevation of Lowest Corner

Kind of Material Excavated.................................

....

Instructions to Contractor.................................

....

....

....

....

NOTE.—On diagrams draw lines indicating bridge tangent line and give distances of centre points of sides and ends of crib low corner and give amount of each other corner above low

Fig. 61*e*

FORM FOR DETAIL REPORT OF CEMENT TESTS

WADDELL & HARRINGTON

CONSULTING ENGINEERS
Kansas City, Mo.

Testing Laboratory at..

....19.....

....Inspector

Tests Made for.......................... Brand..............................

Cement to be Used for...

Car, Bin, or Load No...

Our No. Rwy. No. Initial or Name, etc.

Date Delivered...19..

Total Amount....Bbls. No. of Samples Taken.... Each Test Represents....Bbls.

Tensile Tests.................... Sample No..........................

Briquette No.	Date When Made	Time in Air	Age When Broken	Breaking Load	Remarks	Fineness Reqd. Tested
1						On No. 200, 75%....
2						On No. 100, 92%....
3						Soundness
4						Normal............
5						Accelerated.........
6						Time of Setting
7						First Set.....Minutes
8						Hard Set....H....M.
9						Reqd. 30 Min. and 3 Hours

Tensile Tests.................... Sample No..........................

Briquette No.	Date When Made	Time In Air	Age When Broken	Breaking Load	Remarks	Fineness Reqd. Tested
1						On No. 200, 75%....
2						On No. 100, 92%....
3						Soundness
4						Normal............
5						Accelerated.........
6						Time of Setting
7						First Set....Minutes. Hard Set...H.....M.
8						Reqd. 30 Min. and 3 Hours
9						

Car No................ Accepted or Rejected............19..........

[illegible]

DAILY PROGRESS REPORT

Figures on this sheet [illegible]

Resident Engineer, [illegible]

WADDELL & HARRINGTON

CONSULTING ENGINEERS

Kansas City, Mo.

DAILY PROGRESS REPORT ON SUPERSTRUCTURE

Name of Structure.................... Date.......

Weather............ Temperature............... [illegible]

STEELWORK—ERECTION

Span No.	Weight in Pounds					[illegible]
	Total Estimated	Delivered Today *	In Place Last Report	Erected Today *	Total Erected To Date *	
Viaduct						
Totals						

… ON SUPERSTRUCTURE

… Fill in columns marked*

MISCELLANEOUS MATERIALS AND WORK

Classification	[illegible]	Delivered*	In Place Last Report	Placed Today	In Place To Date	Remarks*
Bbls.						
Cu. Yds.						
Cu. Yds.						
forcing Metal Lbs.						
Rails, etc., Lbs.						
Sq. Yds.						
Estimated M.						
Computed M.						

Contractor's Force*			Engineer's Staff*		
Men	Plant	Worked at	Name	Hours	Worked at
Watchmen, etc.					

....

Resident Engineer

FIG. 61*g*

DAILY PROGRESS REPORT SHEET FOR
REINFORCED CONCRETE STRUCTURES

NOTE—Figures on this sheet merely approximate Sheet No. 8

Resident Engineer, fill in columns marked*

WADDELL & HARRINGTON
CONSULTING ENGINEERS
KANSAS CITY, MO.

DAILY PROGRESS REPORT ON

No.............

Name of Structure........................ Date............................

Weather.................. Temperature..........

Quantities		Total Esti-mated	In Place Last Report	Placed* Today	Total in Place	Work in Progress Today*
Concrete in						
Abutments	cu. yds.					
" Piers	cu. yds.					
" Arches or Gird's	cu. yds.					
" Floor System	cu. yds.					
Pavement	sq. yds.					
Hand Rail	lin. ft.					

Materials		Amount Required	Total Used	Used Today*	Left on Hand*	Remarks
Cement	bbls.					
Sand	cu. yds.					
Stone	cu. yds.					
Reinforcing Metal	lbs.					
Form Lumber	M.					
Falsework	lin. ft.					

FOUNDATION EXCAVATIONS AND PIER SINKING

Piers—Nos.	1	2	3	4	5	6	7	
Final Elevation, cutting edge								
Settled today *								
Elevation today *								
LAND EXCAVATIONS AT								
Total Excavation Required ft.*								
Total last report ft.								
Excavated today (depth in ft.)*								

FIG. 61*g*—*Continued*

DAILY PROGRESS REPORT SHEET FOR
REINFORCED CONCRETE STRUCTURES

Note.—Figures on this sheet merely approximate Sheet No. 8

Resident Engineer, fill in columns marked*

CONTRACTOR'S FORCE*			ENGINEERING STAFF*		
No. Men	**Plant**	**Worked at**	**Name**	**Hours**	**Worked at**
....	....	....	....	......	....
....	....	....	....	......	....
....	....	....	....	......	....
....	....	....	....	......	....
	Supts., Clerks, Watchmen, etc.				
	Total Men				

Resident Engineer

FIG. 61*h*. Form for Percentage Report of Work.

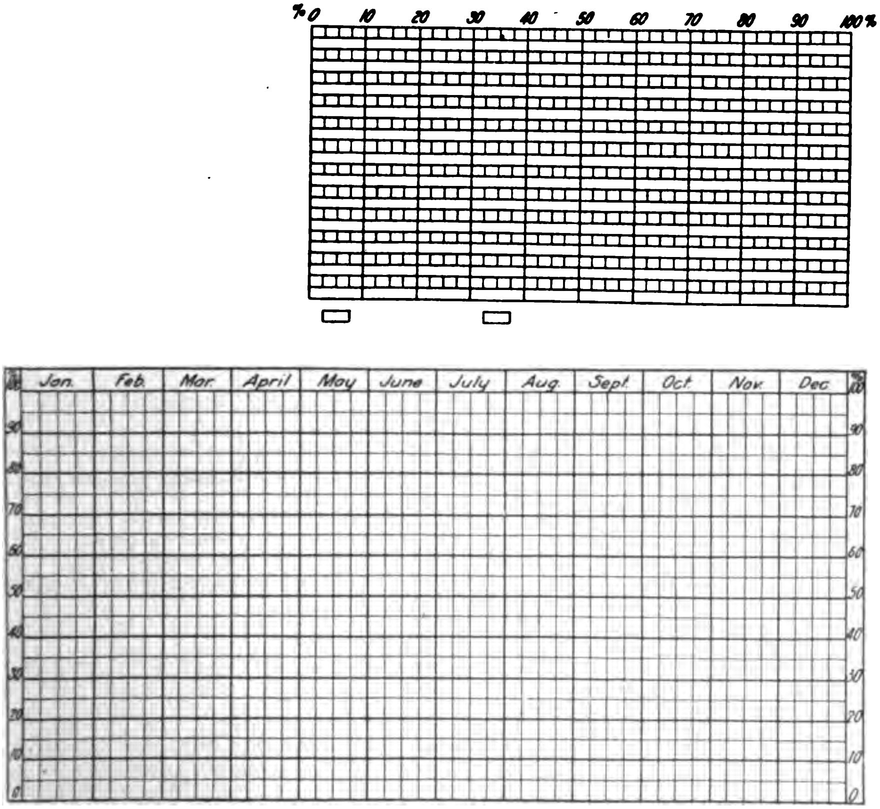


FIG. 61*i*

FORM FOR

SUMMARY OF CEMENT TESTS

WADDELL & HARRINGTON
CONSULTING ENGINEERS
KANSAS CITY, MO.

Testing Laboratory at.................................. .

....19....

.............................Inspector

Tests Made for........................ Brand...............................

Cement to be Used for...

Car, Bin, or Load No......, ...Date Delivered.....19....
Our No. Rwy. No. Initial or Name, etc.

Total Amount....Bbls. No. of Samples taken.... Each Test Represents.....Bbls.

FINENESS TESTS		SOUNDNESS TESTS	Normal	Accelerated
Required to pass 200 sieve	92 per cent			
Required to pass 100 sieve	75 per cent			
Highest.........		No. of Tests O. K.	....	....
Lowest..........		No. of Tests Failed	....	....
Average.........				

TENSILE TESTS

Required	1 day 150	7 day 350	28 day 500
Highest.......	....	....	....
Lowest........	....	....	....
Average.......	....	....	....

SAND TENSILE TESTS

7 day 125	28 day 175
....	....
....	....
....	....

REMARKS..

....

....

....

....

Car No............. ACCEPTED OR REJECTED................19....

Averages given are for all the tests made

FIG. 61*j*
REPORT FORM FOR UNCLASSIFIED WORK

WADDELL & HARRINGTON
CONSULTING ENGINEERS
KANSAS CITY, MO.

For Unclassified Work done During month	Contract No..............
	Estimate No..............
ending....................	Bill No..................

UNCLASSIFIED WORK BILL

For work or materials which are not covered, or implied as covered, by the plans and specifications, under any price in the Contract.

By (Contractor)..

For (Purchaser)..

On (Job)...

COPY OF ORDER FROM ENGINEER

WADDELL & HARRINGTON By....................

ITEMIZED BILL

Total Amount Due......................

Approved: WADDELL & HARRINGTON By..........................
Resident Engineer

Bills for Unclassified Work are to be rendered monthly and included in the regular estimate.

One copy of this bill to be pasted to each copy of estimate.

The receipted vouchers for all items of this bill are to be sent to the main office. The Contractor is to prepare the bill with all copies desired, on this form, which will be furnished by the Resident Engineer.

Fig. [illegible]

MONTHLY STATEMENT FORM FOR [illegible]

WADDELL & HARRINGTON
CONSULTING ENGINEERS
Kansas City, Mo.

For...

....

Statement of work done by...

During month of.................19.... **Statement No**..........

Items Bill No.	Expenditures During Month	Plus per Cent as Applicable	Amount Paid Directly by Owner	[illegible]
		Amount due by	this statement	

Remarks:

We certify that this statement is correct

Waddell & Harrington
Consulting Engineers

By...

CHAPTER LXII

ERECTION AND FALSEWORK

VARIOUS methods for erecting bridges have been developed to fit the different types of structures and the diverse conditions prevailing at the bridge sites. These methods may conveniently be grouped in two general classes, viz.:

First, erection with falsework; and second, erection without falsework.

The choice between these two methods will depend on the type of structure and the conditions at the bridge site. As a help in making such a choice for any particular case, the salient features of each method will be briefly set forth. The several types of bridge spans that the erector may be called upon to build are as follows:

1. Masonry arches.
2. Concrete girders and arches, both plain and reinforced.
3. Steel girders.
4. Viaducts and elevated railroads.
5. Truss spans.
6. Movable spans.
7. Suspension bridges.

Where a span is composed of numerous members that have to be assembled in final position, such as trusses, it is usually best and most economical to employ falsework, if the conditions at the site permit. Likewise, masonry and concrete arches, which require continuous support, are constructed on falsework, or centres, as the same is frequently termed. Those conditions at site favorable to the building of falsework are a river bed that will permit the driving of piles, an interval between floods sufficient to allow of the span or spans being assembled, riveted up, and swung, freedom from interference by river navigation, and the absence of deep water, swift current, drift-wood, and ice.

For single-track truss-spans, where no passing trains have to be provided for, it is customary to use falsework consisting of four-pile bents driven at intervals to correspond with the panel points of the truss. If a traveller is to be employed in erection, these bents are made wide enough to permit the placing at each end of a pair of 8″ × 16″ stringers outside of the span in order to support the rails on which the traveller runs. For shorter spans, where a derrick car will handle the material satisfactorily, the bents need be wide enough to carry only the two trusses. If the piles are sufficiently long to reach to the top of the falsework, they are capped with 12″ × 12″ timbers and sway-braced with 4″ × 8″ planks. In case

[illegible]

used to tie the bents
the height of the bents exceeds
firm bed or hard bottom, framed bents
economical. The posts are usually 12
pieces battered to give additional stability
dinal wales correspond to those in pile bents

Should provision have to be made for
bridge during erection, six piles or posts are
longitudinal bracing similar to that required
to be provided, in order to resist the thrust
designing of falsework, the reader is referred
"Wooden Bridges and Trestles," where he
working stresses and other necessary

It is usually desirable to erect the floor
the trusses; but occasionally it is best to
question is discussed quite fully by Mr.
truss connections are to be riveted up as soon
members are erected, in order that the span
case the falsework is washed out.

For spans over 250 feet in length, erection
of a traveller. This is essentially a frame-
verted U, supported on at least four rollers or
laid along the stringers of the falsework previous
lows of the traveller's being readily moved along
the top are convenient platforms for the
each side are hung several sets of blocks and
bers of the truss. A hoisting engine is mounted
operating the tackle. Frequently swinging booms
ward corners so that they can be handled like a
lever bridges it is practicable to employ one or two
tively speaking, travellers or "mules" riding on the top
up the material for erection from cars on the deck
under 250 feet and for trestles and elevated railroads
be dispensed with and a derrick car or locomotive
the parts into place.

The falsework, or centering, for masonry and concrete
complicated than that required for truss spans, because
of the arch necessitates special construction, and because
distributed along the span length instead of being
points, as in trusses. This latter calls for continuous
lagging and beams are necessary to transfer the
or bearings. Furthermore, the centering must be
sist the distortions produced by partial or unsymmetrical

tlement of the supports is to be avoided as much as possible. Centering is sometimes built on top of temporary trusses, but in such cases provision must be made to offset the deflection of such trusses. Further provision must be made for a gradual lowering of these centres so as to bring every part of the arch into action at the same time. This is readily accomplished by using wedges under the centres, which wedges can be gradually loosened at all the supports. Sand-jacks are also frequently employed for the same purpose.

Where conditions do not admit of falseworks being constructed, truss-spans may be erected on barges at some distance, if need be, from the site and then floated into place and lowered onto the piers. This lowering is accomplished by means of jacks or by taking on water ballast. This method was adopted for the spread span of the author's bridge over the Fraser River at New Westminster, B. C. In that instance a depth of water of 80 feet and a reversing current of five miles per hour were encountered. The spread span, which was about 232 feet long and 136 feet wide at the wide end, while the narrow end was of the ordinary width of 19 feet, was erected on three barges placed in triangular formation, as shown in Fig. 62*a*. These were then floated into proper place, water ballast was admitted, and the span was thus lowered into final position on its piers. A detailed description, setting forth some of the unique features of the work, is given in the *Engineering Record*, Vol. 50, pages 192 to 194 inclusive.

FIG. 62*a*. Floating the Spread Span of the Fraser River Bridge into Place.

Where it is not practicable to build falsework nor to erect the span on barges and float it into place, the structure can be erected by the

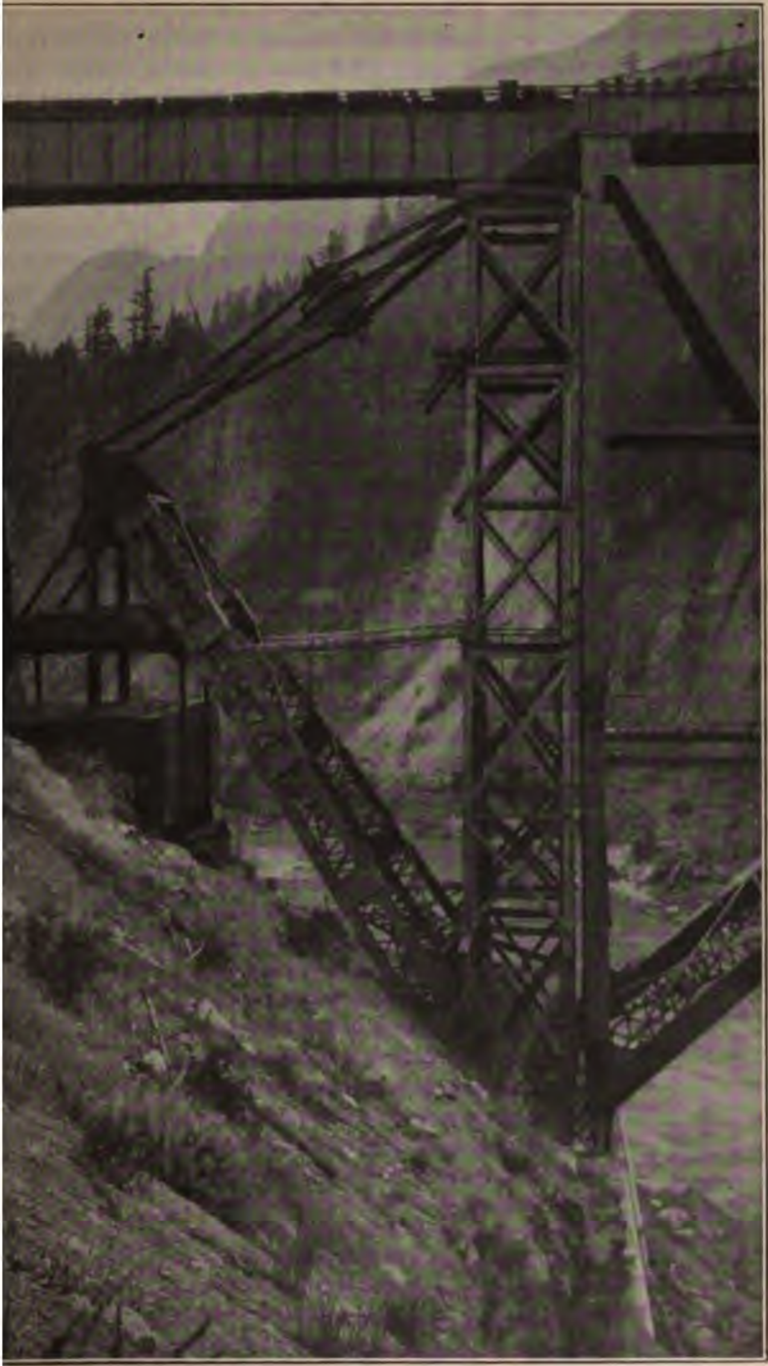
cantilever method. In this case
stiffening the bridge to take care of
the temporary and unusual loading
earliest of this method of erection,
Bridge for the Cincinnati, New
twenty-one miles south of Lexington
method of erecting simple spans was
a quarter of a century ago, and has lately

Fig. 62b. Cantilever Erection of the
Bridge over the Fraser River

bridges for the Canadian Northern Pacific
Fraser and the Thompson rivers in British
current and hard bottom prevented the use of
channels of both rivers. In the Fraser River
which was 290 feet long, was erected from
out from each adjacent span; but for one of the
work could proceed from only one end, so that
several contiguous spans by cantilevering the
feet. Fig. 25*g* gives a view of the Fraser River
tion of semi-cantilevering.

Trussed arches are often erected by the
the early examples of this was the erection of the
in *Engineering News*, Vol. 37, page 252. A later
River Bridge for the Oregon Trunk Railway,
News, Vol. 69, page 549.

The author's 425′ arch span near Cisco over
erected by cantilevering out the two halves till



62c. Counterweight for Anchoring, During Erection, the South Half of the Arch Span of the Canadian Northern Pacific Railway Bridge over the Fraser River.

[illegible]

[illegible] American Society of Civil [illegible] type of structure not [illegible] usually set in place by means of [illegible] locomotive crane.

[illegible] method of erection, and [illegible] launching the span endwise into place [illegible] final position. This is accomplished [illegible] projecting truss to the end of the [illegible] the combined structure forward on [illegible] the desired position, when it is [illegible] been frequently used in Europe for [illegible] is the Jean François Lepin Bridge over [illegible] The main span was 144 feet and weighed [illegible] porary projecting framework was nearly [illegible] 56 tons. An illustrated account of this [illegible] be found in the *Engineering Record*, Vol. [illegible] instance of launching a span by the [illegible] pension cables and a hinged boom is given in [illegible] Canadian Society of Civil Engineers, Vol. XVIII, [illegible] of the Reventazon River Bridge in Costa Rica, [illegible] was launched on rollers by employing a [illegible] to support the structure until it had moved into [illegible] was jacked up and the rollers were taken out; and [illegible] into position. See *Engineering Record*, Vol. 61, [illegible]

The erection of a suspension bridge begins at [illegible] are constructed, the strands composing the [illegible] end, then carried up over the saddles on the [illegible] ing, by various means, to the next tower, which [illegible] into the anchorage. A moving platform or [illegible] cable so that workmen may wrap it with coils [illegible] or place clamps and suspenders in position for [illegible] To these suspenders are hung the stiffening [illegible] generally by starting at the end of the bridge and [illegible] with boom of sufficient length to reach one or [illegible]

The organization needed for carrying on a [illegible]

course, depend very much on the size and class of bridge that is being constructed. The erection of steel structures calls for a special type of skilled workmen. In the larger jobs it is usual to have a crew of erectors, another crew of riveters, and still another crew for pile driving. In addition to those special crews it is desirable to have a gang of men for handling material. In the smaller jobs this division of labor is not carried out so extensively.

The usual equipment comprises a pile driver with hoisting engine for falsework construction, a derrick car for erecting the smaller spans, and a traveller with one or two hoisting engines for the larger spans. Several push cars for convenient transportation of materials are needed. For riveting, a pneumatic outfit is best, as more rivets per gang per day can be driven, and as there will be fewer loose rivets to cut out and replace. Moreover, modern specifications for bridge erecting demand that pneumatic riveters be employed for field riveting. Forges will be required for heating the rivets. These should usually be operated by hand, as there is then less danger of burning the rivets; but for large rivets the use of oil forges, operated by compressed air, is necessary. If the pneumatic plant is not installed, sledges will be needed for hand riveting. Various small tools, wrenches, drift pins, reamers, connecting bolts, etc., will have to be provided.

The erection of reinforced-concrete bridges is quite fully treated on page 946 *et seq.;* and certain features of erection work are discussed in Chapters LXIII and LXV.

For further information on the subject of erection and falsework the reader is referred to such standard works on bridges as those of Johnson, Bryan, and Turneaure, and Merriman and Jacoby. Special mention should be made of the excellent illustrated chapter on "Adjusting and Erection Devices," in Prof. C. W. Hudson's book, "Deflections and Statically Indeterminate Stresses."

CHAPTER LXIII

MAINTENANCE OF TRAFFIC

The problem of maintaining traffic on an
an old bridge with a new one becomes in some
ter, and may involve such serious complications as
sign of the new structure. Various methods of
been employed, each one having some special
of conditions. As a guide to a choice of methods
features of each are herewith set forth.

Where trains are more than a half hour apart
be driven beneath or through the structure, it will
falsework under the old superstructure, remove the
erect the new span on the same supports, and
work. This timber construction must be desig
load as well as the weight of the span; and it should
tudinal bracing in order to withstand safely the thrust
In Chapter LXII will be found a description of
falsework suitable for various conditions. This
advantage directly as the interval between trains.

For those cases where the service is more freq
each half hour during a considerable portion of the
best to build, if possible, a by-pass or run-around.
or timber trestle. If river traffic has also to be
necessary to have a movable span in the said trestle
of the passage of boats. This movable span may
arranged to act as a lift span, or a bascule, or in
may be pivoted at one end on the corner and have the
by a barge when in operation.

In rare cases the existing superstructure may
the new span and to carry also a limited train servic
cumstances the falsework can be dispensed with; but
essary that the perpendicular distance between
of the new span exceed that of the old one sufficien
new construction surrounding that which is to be
is seldom employed, because nearly all renewals
strength of the old structures, which generally
carry their own weight in addition to the live load
sustain the weight of the new steel. However,
it necessary to adopt this method. Such was the

where the Norfolk and Western Railway had to renew its bridge across the Ohio River. It was important that every precaution should be taken to prevent accidents during reconstruction, as the nearest river crossing above Kenova was at Point Pleasant, 60 miles away, and the next nearest crossing was at Cincinnati, 150 miles down stream. The variation in water level amounted to some 70 feet between flood and low-water elevations, and provision had to be made for river navigation at all times during reconstruction. On account of these strenuous conditions and because of the very heavy traffic, the contract stipulated that no falsework should be placed in the river. The method finally adopted was to construct falsework only under the stringers of the end spans, which, at ordinary stages of the river, were over dry ground, then to disconnect the stringers from the floor-beams, leaving the falsework to carry the old stringers, the old track, and the live load. The new floor-beams were then suspended from the old ones by rods, and the new spans were built up around the old ones on brackets attached to the ends of the new floor-beams in their suspended position. After the new trusses were swung, the old spans were blocked up on them and dismantled, the brackets were taken off the new floor-beams, the latter were hoisted to proper elevation and riveted into the posts, the new stringers were inserted and attached, the new lateral bracing was put in, and the track was laid. Of course, there was for each span a short interval when it was incapable of withstanding much wind pressure because of its lack of lateral bracing. By choosing quiet weather and working quickly it was possible to reduce this danger to a minimum.

The spans adjacent to the end ones were erected by cantilevering out their full length from the finished spans, building around the existing structure and depending upon it for lateral resistance, then making the new trusses support the old span, removing the latter piecemeal, and putting in the new floor system and new lateral system.

Finally, the long central span was erected in two parts by cantilevering from the two adjacent finished spans until the half trusses met at the centre, when they were connected and swung, and then they were made to support the old span while it was being demolished and while the new floor system and new lower lateral system were being inserted. An account of this reconstruction is given in the January, 1915, *Proceedings* of the American Society of Civil Engineers.

The renewal of an old bridge often calls for the construction of new substructure. If a slight change in alignment of track can be made, and if the conditions are favorable for the building of falsework, it will be found economical to erect the new spans on falsework alongside of the old bridge and extended underneath the latter for the purpose of demolition. When the erection is completed, a cutting and shifting of the tracks can readily be made, and then the traffic can be transferred to the new structure. In this way practically all interruption thereof will be

[illegible]
[illegible] to do the shifting properly [illegible]

Where the water is too deep or the [illegible]
be constructed and maintained safely, the [illegible]
upon barges and floating them to [illegible]
advantage. In this case the spans are [illegible]
shore, and then two or more barges—the [illegible]
and the span length—are partially filled with [illegible]
the span between the falsework bents. Then [illegible]
the load is transferred from the falsework to the [illegible]
is pumped therefrom. In the meantime barges [illegible]
the old spans, and blocking has been placed so [illegible]
the piers and transferred to the barges. The [illegible]
span are then brought near to their position at the [illegible]
span moves out the new span moves in. When [illegible]
it is lowered into place either by the removal of [illegible]
by flooding the barges. After landing the new [illegible]
rails are connected and traffic is resumed. This [illegible]
of conditions consumes several hours of time and [illegible]
to a corresponding extent. It also requires [illegible]
barges and tug boats. It was used in reconstructing [illegible]
across the St. Lawrence River by the Grand Trunk [illegible]
A detailed account of the work will be found in the [illegible]
Vol. 62, page 628. This bridge was out of service only [illegible]
each span.

It seems hardly necessary to suggest that if the [illegible]
where rising and falling of the water level occur [illegible]
the barges can be run under the new span at low tide [illegible]
be lifted off its bearings at half tide and floated into [illegible]
tide; and finally the barges may be removed as the [illegible]
ating the necessity of flooding them, pumping them [illegible]
them again.

Under some conditions where falsework cannot be [illegible]
there are several duplicate spans to be replaced, [illegible]
set of barges for one new span and upon another [illegible]
then when a span is torn down and replaced, the [illegible]
imposed falsework are moved ahead to the next [illegible]
just described are repeated. This method is not [illegible]
tuation in water level; but small changes of a foot [illegible]
care of by means of water ballast, which can be [illegible]
as the case may require.

Another method of replacing an old span, [illegible]
quent and interruption of traffic is not allowable [illegible]
new span alongside of the old one, supporting [illegible]

falsework sufficiently strong
raise the old span and place a
with rollers between the tiers of rails. By means
tackle and a hoisting engine or locomotive at each
span is moved out of place and the new one moved
are removed, and the span is lowered to a
difficulty encountered in this method is the
bringing excessive concentrations on the end floor
Usually there is very little working room
and operating the jacks. Various expedients
and loading beams have been devised in order
the end pins. A good example of this arrangement
suspenders is that used in the reconstruction of the
over the Ohio River for the Pittsburg Division of the
Chicago and St. Louis Railway. In this case the
heavy; and, therefore, unusual care had to be
spans weighed 3,100,000 lbs. gross each, and another
lbs. gross. The time consumed in moving each
was forty-three minutes. Within this interval the
the weight of the old spans was transferred
rolling carriages, the old and the new spans were
new spans were lowered to their permanent position
the tracks were re-connected. The time consumed in
span was only seventeen minutes. A good account
found in the *Engineering Record*, Vol. 62, page 596.
had occasion on some of his work to move spans longi-
piers to permanent piers without interrupting
Rio Blanco Bridge on the Vera Cruz and Pacific
truss span weighing 240 tons had to be moved
The span was erected on timber piers, as there was
build permanent substructure and then erect the
water period. This expedient gave the railroad
over a deep and swift river that could not otherwise
the flood season, which lasted several months.
again subsided to a normal dry-season flow, the
constructed, then the spaces between these and the
filled with substantial falsework sufficiently strong
span. On top of the deck were placed railroad
having a slight pitch downward toward the new
slipped under the shoes of the span, and ex-
thus forming ways for the span to slide upon.
and attached to the end of the span, and
for the operation. It was found that this

was not sufficient to start the mass
set up in inclined positions under the end
was taken out of the tackle, and the jacks were
thus giving a "kick" to the span, after which the
is in motion. The entire movement occupied about
actual start was made.

Another instance of moving spans longitudinally
souri Pacific Railroad Bridge across the Kaw River
this instance three double-track spans had to be
feet, moved laterally about twenty-five feet, and
one hundred and twenty-five feet. For the lateral
work was constructed so as to support the structure
new position. Two tiers of rails with two-inch steel
placed under each shoe. Blocks and tackle were placed
the several spans, and hoisting engines were used to
the lateral movement was accomplished, special trucks
each having six standard car wheels with their axles
were distributed under the spans, so as to spread the
possible. These trucks rolled on rails placed upon the
neath the bridge. The movement of the mass was
bined stressing of the tackle, operating jacks set on
points under the shoes, and pushing with a locomotive
strut against the end floor-beam. The entire movement
three minutes. A good description of this work, with
be found in *Engineering News*, Vol. 70, page 54.

In either double-tracking an existing single-track
it by another single-track one, where plate girders of
are adopted to replace old through truss spans, and
able to avoid building falsework, it is a good plan to
end of the structure several gallows frames at convenient
pending on the length of the said girders, and to place
of each truss span several heavy cross beams or "ji
the girders are to be placed outside of the old trusses,
cantilever over the chords a sufficient distance to
Two sets of blocks and tackle are then to be rigged
frame and each jigger; and the girder is to be picked
tackles, and attached to the next forward tackle,
put upon the latter. If the girder goes inside of the
tem must be cut loose from the trusses and gotten
the stress on the forward tackle is increased, a
to be given to the girder, and then the head support
eased off gradually, detached from the front end
attached to the rear end thereof. A stress is then
last mentioned tackle and the rear tackle released,
mit the girder to swing forward. This operation

the next set of tackle until the girder has reached the proper position for lowering on the piers. After the girders are placed and the floor system is completed, it is usually an easy matter to dismantle the old trusses with a derrick car on the track. A good illustration of this method was the replacing of truss spans on the Auburn Division of the Lehigh Valley Railroad at Weedsport, N. Y., an account of which is given in the *Engineering Record*, Vol. 60, page 290. A somewhat similar method was that adopted by the Duluth, South Shore, and Atlantic Railway Company on its line at the Bad River crossing near Shilo, Wis., where a 150-foot Howe truss span was replaced by a 121-foot plate girder span. The latter was assembled on two flat cars, riveted up completely, and then hauled out on the truss span. One end was picked up by a gallows frame, previously erected at the shore end of the Howe-truss span, and the other end was supported by a derrick car. After lifting the span off the cars, which were then run back to shore, the deck members of the truss span were removed, one piece at a time, and dropped into the river below, from which they were afterward fished out. The girder span was then lowered to position between the old trusses, which were later removed at convenience. The time occupied in moving the span out from shore, setting it in place, and connecting up the track was five hours.

Where a double-track structure of reinforced concrete girders or arches is to displace an old bridge, it is usually possible to build a longitudinal half of the entire concrete construction while traffic is being taken care of on a single track of the old bridge. When this first portion of the concrete work is finished, the track is shifted to its deck, and the old structure is demolished; after which the remainder of the concrete is placed and the bridge is completed. An example of this is the renewal of the Gwynns Falls Bridge in the city of Baltimore for the Philadelphia, Baltimore, and Washington Railroad. In this case traffic was maintained on the old structure while the first half of the new bridge was built. When this was finished, tracks were laid over it, and the traffic was diverted from the old bridge, which was then dismantled. This permitted the finishing of the remaining half of the concrete work without interrupting traffic.

Many variations and combinations of the foregoing described methods are to be met with in practice. Each case had to be studied by itself and the method of construction adjusted to suit its peculiarities.

In all this work precautions must be taken to carry out the regulations of the operating department of the railroad in regard to lights, signals, and flagging trains.

In preparing this chapter the author received many valuable suggestions from L. S. Stewart, Esq., President, and H. K. Seltzer, Esq., C. E., Vice-President of the Union Bridge and Construction Company of Kansas City, one of the best known bridge building companies of America, for which help he desires to express here his hearty thanks.

CHAPTER LXIV

BRIDGE EXAMINATION

This examination of old structures constitutes the practice of some bridge specialists. Although or satisfactory professional work as the designing just as important; for upon the skill, experience tegrity of the engineer who examines and reports railway and highway bridges depends the safety of No one except an experienced bridge engineer should examine and report on such structures, because apt to overlook many important matters when and often it requires rare judgment to determine should be passed as sufficiently strong, ordered to be removed.

The objects of bridge inspection are as follows:

A. To discover weaknesses or defects and how

B. To ascertain the amount of deterioration of if possible, its rate, in order to figure upon its probable of life.

C. To determine the safety of the structure conditions of loading.

D. To decide upon whether there is any necessity forcements, or renewals, what these should be, and

E. To settle as to what should be done in order loads safely while repairs or renewals are in progress.

The frequency with which bridge inspections should upon a variety of conditions, among which may be acter of the structure, its location, its strength, and condition. Bridges built of late years on scientific thorough inspection may need but a single inspection some old and unscientifically designed ones may require carefully every few weeks, or in extreme cases every

For railroad bridges a special committee of the Engineering Association recommends the following

"(1) Inspection by the regular section forces, daily, or the track under their supervision. The object of this damage to the structure from fire, flood, derailments, or or any displacement in the structure in whole or in part. the lack of skill on the part of the section forces must

will rarely, if ever, do more than call attention to unsafe conditions arising from causes other than those of natural depreciation. No reports of such inspections need be made unless adverse conditions are discovered.

"(2) At periodic intervals of from one to six months there should be inspections by bridge foremen or others experienced in bridge repairs. These inspections should be more thorough than those of the section forces, and are intended to discover all the defects, arising from traffic, to which the bridge is subjected, and those due to natural depreciation or other cause. Reports of such inspections should be made to the one next in authority; preferably to the one most directly or primarily responsible for the safety of the structure.

"(3) Annual or semi-annual inspections are to be made by men experienced in the design and maintenance of bridges; preferably by those who are primarily responsible for their safe maintenance. The reports of these inspections should be filed, and in connection with an examination of office data they will determine the safety of the structures, and will be the basis for decisions as to repairs, reinforcements, or renewals.

"The inspections outlined in (1), (2) and (3) above must be considered as quite general. There will often be cases where much more frequent and thorough inspection than above outlined will be necessary, especially for structures which are carrying traffic much heavier than that for which they were designed, or which, by reason of poor design, age, or injury of any kind, have a reduced margin of safety. Because of inability to renew some bridges in time for changed traffic conditions, uncertainties as to revision work, lack of time for replacement after injury, or other reasons, it is occasionally necessary to keep in service structures which have not the usual margin of safety. The manner and frequency of the inspection necessary safely to maintain such structures must be determined separately for each individual case.

"Railway bridges are of timber, masonry, or metal, and occasionally of unusual design; men competent to inspect one kind are often incompetent to inspect other kinds, and, therefore, it may be necessary to limit an inspector to structures of a certain kind. It is sometimes desirable to have large and important or doubtful structures inspected by expert engineers."

This last remark of the committee's does not carry with it sufficient force; because it is highly advisable for every railroad company to have all its bridges examined and reported upon from time to time by an expert who is not regularly in its employ. He is likely to discover some important facts that have been overlooked by the regular employees of the road. Such occasional examinations to a certain extent serve as a partial protection to the company against excessive claims for damages due to bridge accidents; because, if it is shown that the company took the precaution to secure expert opinion concerning the safety of its bridges, any jury is likely to conclude that it did all in its power to avert the accident.

As long ago as 1887, in a discussion at the Annual Convention of the American Society of Civil Engineers upon the subject of "Inspection and Maintenance of Railway Structures," the author wrote as follows in answer to the question, "What is proper bridge inspection?" and, as he has had no occasion since to change his mind about any of the points therein covered, he has decided to reproduce here verbatim that part of his discussion. It reads thus:

"There are two kind of bridge inspection,
"A. Inspection of structures the dimensions of
"B. Inspection of structures the dimensions of
The former is, of course, much more extensive and
should be made as follows or in some similar way:
"I. Measure systematically the main dimensions of
tions of all the principal members, recording them always in a
mined by experience to be the best, so that any particular
diately by inspecting the field notes, which, by the way,

"II. Measure and record systematically the sizes of all
of each panel point and each connection of main members,
and diameter of rivets, the packing, including the distance of
from plane of symmetry, dimensions of eye-bar heads,
short, every dimension that could under any circumstances

"III. Measure and record systematically all the details of
panel points or connections, for instance, sizes of lacing bars,
angles, etc.

"IV. Examine the structure carefully so as to find any
design, such as loose or unequally stressed tension members,
of fillers, bad riveting, twisted or otherwise distorted
loose connections, etc., also the various effects of wear, such as
rust, decayed timber, cracked castings, and defective
pedestals.

"V. Look to the efficiency of the floor system proper,
guards, also to the means of protecting the structure from injury
vibration, etc.

"VI. Examine thoroughly and make notes upon the
principal measurements, quality and condition of materials,
ing of the stream or chasm, noting, if possible, high and low
and any other information that may be of use.

"VII. Note the effect upon the bridge of rapidly passing
recording, if thought necessary, the deflections.

"VIII. Note, if possible, the names of the designer and the
the date of erection.

"IX. Record in the note-book the names of the members of
party, the date, and the time spent in making measurements.

"The inspection of structures the dimensions of which are
made simply with the view of ascertaining the effect of wear,
The items are mentioned under the previous headings
VII. Before making such an inspection, the inspector should
notes of the previous inspections, and determine where to look
of wear."

When one is examining a bridge of which the
at hand, he should check the structure at a number of
to make sure that it was really built in accordance
ings; and if it be found that in any particular
ment, the drawings should be discarded entirely, and
be examined and measured in exactly the same
would have to be were no drawings available.

The character of the material of which the
was built is sometimes difficult to determine.

but generally it can be found only in the speci- the bridge was built, and too often these cannot the date of erection and the name of the manufac- ed on the structure will lead to securing the de- any rate, they will determine whether the metal steel, and, if the latter, whether it was manufactured the open-hearth process. As a last resort, one can and test it; but this is seldom done, mainly because volved, but also because such a test would cover only metal, which may have been purchased from sev- mills. In testing an old bridge the author does not determine the character of the metal. If he knows it he assumes that it had an elastic limit of 25,000 pounds an ultimate strength of 50,000 pounds per square inch, be steel, he assumes instead 30,000 pounds and 60,000

things for an inspecting engineer to determine is deterioration of metal by rust. It is usually easy to the original dimensions of any section; for rust does uniformly; hence one can find places where the member by measuring the section at the points of greatest determine the percentage of lost area. By obtain- at several places and striking an average thereof maximum, as his judgment may dictate, one can obtain of deterioration to apply to the metal of the whole yet to certain parts of it; for the deterioration will be the floor system, and the lateral system. If a been badly neglected and allowed to rust, it must be rusting is by no means as serious as it looks, for are from five to eight times as thick as the metal and removed.

be constantly on the lookout for injuries to the from passing trains or falling objects, or by loco- drippings from refrigerator cars.

workmanship on the metal can be determined generally customary for the inspecting engineer to unless he encounter some glaring evidence to

rivets is done by a combination of three senses, hearing. Of course, it is not necessary to tap the rivets in a structure, for the experienced where to examine for loose ones; and if he twenty (20) per cent of all the rivets in any there are none in the remainder of the said

[illegible] All such [illegible]
[illegible] as to prevent the entrance of [illegible]
[illegible] timber. [illegible]

The condition of the flooring pavements, [illegible]
careful attention, and the open spaces [illegible]
abutments require special pains in examination [illegible]
to occur at such points, especially in old style [illegible]

The soundness of old stone masonry is [illegible]
idea of it may be obtained by making an [illegible]
with small steel rods. If any great penetration [illegible]
is faulty and will need attention. Concrete [illegible]
spected, as its defects are likely to be on the [illegible]

Foundations should be examined for the effects [illegible]
parts of pier shafts for abrasion by ice and drift. [illegible]
posed, they should be inspected carefully for [illegible]

When examining a series of bridges for a [illegible]
has made a practice of requesting the use of a [illegible]
locomotive, a heavily loaded freight-car or two, [illegible]
inspecting party is to be several days on the [illegible]
for board and lodging along the line are not [illegible]
a private car to the end of the train. Quite often [illegible]
the superintendent, or the chief engineer will join [illegible]
and accommodate it by the loan of his private car. [illegible]
is measured and inspected, it is to be tested for [illegible]
deflectometer upon it, preferably at mid-span, [illegible]
weight resting on the river bed, and measuring the [illegible]
tions (exaggerated twofold on the recording paper), [illegible]
at rest in the position which will produce the [illegible]
then at different velocities gradually increased until [illegible]
able limit of speed of train is reached or prudence [illegible]
further risk of wrecking the structure. The ratio of [illegible]
flection to the static deflection minus unity will give the [illegible]
pact for the span as a whole under the train velocity [illegible]
velocity has to be determined approximately by noting [illegible]
pied by the train in passing a measured stretch of track [illegible]
judgment of the engine driver or train conductor.

In making the computations for actual intensities [illegible]
one should assume a live load of the usual type [illegible]
loads that either pass over the line ordinarily or [illegible]
pass over it in the immediate future. To the [illegible]
from this assumed live load are to be added the [illegible]
pact and the dead load stresses computed from [illegible]
structure. Generally an experienced bridge [illegible]

measurements of members.
which the bridge was manufactured is a
assumed dead load recorded on it will suffice, if
matter is necessary.
ponent stresses are written on a stress-diagram
d, then the area of each main member, prop
ection, is written along its axial line, and the
ited and recorded on the sheet. This actual in-
ed with the permissible intensity of the engineer's
g new bridges, and its excess is written on the
, together with the recorded notes of the inspec-
ion for passing or rejecting the structure. The
s to condemn or order strengthened any truss bridge
in which the excess exceeds fifty (50) per cent,
span where it is greater than sixty (60) per cent.
be influenced more or less by the signs of wear that
rivets are in evidence, one can raise slightly the
reverse is the case, it may have to be materially
of a few rivets to some of the connections, pro-
to put them in, will sometimes correct the worst
ture and permit of its being retained in service
. One should be chary about ordering removed
be made serviceable at moderate expense; but, on
should take no chances by risking the lives of the
an endeavor to save money for his clients. Above
should let no latent hope of being retained to de-
for the crossing influence him to condemn to removal
legitimately be strengthened and used.

much it is economic to spend in repairing an
in Chapter LXV. It should receive for each
consideration by the inspecting engineer be-
principal; and his report should set forth clearly
on this important matter. The report should
inion as to the probable safe life of each bridge that
basis, first, of the existing traffic, and, second,
probable future increases in the live loads to be

arises as to what an expert bridge engineer should
reporting upon bridges. The author's practice
tures is to charge one hundred dollars per day
all the time spent in traveling, examining,
retained by a railroad company to examine a
line, and when he is provided with a special

train and all the necessary facilities, he makes an average charge of thirty (30) cents per lineal foot of structure examined, no reduction being allowed for duplicate spans nor for any other condition. These figures are moderate, considering the importance of the work done and the responsibility assumed by the inspecting engineer.

Just as the manuscript of this book was about to go to the printer, Messrs. Hildreth & Co. very kindly sent the author a copy of their standard instructions to assistants in relation to the examination of existing railway bridges; and as these are very complete in detail, he has decided to append them to this chapter, not only because of their thoroughness but also because it is well for the reader to consider the subject from more than a single point of view. The said instructions read as follows:

"INSPECTION OF EXISTING RAILWAY BRIDGES

"GENERAL. Notes should be full and well illustrated by photographs and sketches. Each span must be covered separately and systematically by panels in consecutive order, with the direction to the nearest important station indicated at the first panel point.

"Note character of approaches, grade, and alignment of track. Note size and condition of ties, rails, and rail joints, particularly on bridge and adjacent to bridge—on both sides for 500 feet.

"FOUNDATIONS. Note any evidences of settlement, crack, or movement, particularly any movement tending to 'pinch' the bridge. Make accurate measurements and establish bench marks and reference points so that further movement may be determined.

"ANCHORAGE. Note condition of anchor bolts and nuts and whether there is ample space for expansion and contraction. There should be allowed 1⅝" per 100 feet for range of temperature of 150 degrees, or $^1/_{700}$ of the span. All bearings, particularly roller bearings, must be clear of rubbish. Note any tendency to uplift or overturn bases.

"LINE. Check line of structure with transit, including sighting bottom and top chords. Check line of tower columns for bending, and sight all important members of each span by eye.

"CAMBER. Test with surveyor's level, or for short spans with cord or piano wire stretched between the supports.

"DEFLECTION. Test deflection under maximum load available (preferably two heaviest engines in use, coupled) with surveyor's level, or for short spans with cord or piano wire stretched between the supports, or wire with weight and spring balance at the centre.

"RIVETS. Test all rivets, particularly field connections, with special care for floor connections. In plate girders test carefully rivets near ends and those of lateral and sway connections. Look for rust streaks below rivets, indicating looseness.

"PINS. Look for evidences of wear and bending, particularly at hip verticals. Note movement of pin nuts.

"BEARINGS. Examine all bearings of compression members. Examine stringer ends which, if on shelf angles or top flange angles of floor-beams, should have brackets or web stiffeners beneath the stringer bearing.

"BRACING. Shake all braces and note any which are loose or bent. See that adjustable rods are taking sufficient and uniform tension.

"COUNTERS. Shake all counters and examine carefully to determine that they

should be just tight under dead load and uniformly

eye-bars; they should be under uniform stiff tension.
structure for rust, particularly the details near masonry.
cross section therefrom in each member.
entire structure thoroughly for evidence of defects of ma-
cracks, openings, bending, distortion, or movement of

the passage of a regular train at usual maximum speed, note
on top chord of through bridge or on bottom chord of deck

up including map, showing topography and profile
bend in stream.
and sketch piers and abutments—elevation, section, and
size and location of bridge seats, and the clear span under
walls. Sketch accurately the upper five courses of masonry,
quality and condition of masonry. In case of movement,
test pits adjacent to abutments and make borings close
determine character of soil and its probable bearing capacity.
All data must be secured in order to prepare plans as for a
details, clearances, sections of material, rivet spacing,
a new bridge can with advantage be used as a guide, indicat-

examinations the following instruments, etc., are needed:
transit (or combined instrument), 100-foot steel tape, 200
feet of piano wire, spring balance, plumb bob, 4 to 6 foot
rivets, steel scale, large and small calipers, chalk or paint."

CHAPTER LXV

RECONSTRUCTION, MAINTENANCE, AND REPAIR OF EXISTING BRIDGES

Experience shows that any metal bridge of imperfect design materially overloaded or ineffectively painted deteriorates with age and use, and that there is a limit to the time during which it can perform its function satisfactorily and safely. The continual increase in live loads and also that of the speed of trains tend to hasten the day of its replacement. To prolong its life as much as possible calls for the skill of the bridge expert and requires regularity of attention in order to recognize the smaller defects and deteriorations as they develop and to remedy them before they become serious. This work is included under the term maintenance. Where some accident results in slight damage to the structure beyond the usual wear and tear, necessitating restoration on a more extensive scale than that of ordinary maintenance, the work is embraced under the head of repairs. There is no well-defined line between these two classes of operations; and it is difficult at times properly to classify such work.

Reconstruction may be considered to cover the more extensive repairs and replacements of certain portions of the structure whether necessitated by a serious accident, or by an accelerated deterioration, or by increase in loading. Neither is there a sharp distinction between repairs and reconstruction, but rather a merging of the two classifications. However, it is always well to attempt such a division in order to promote an adequate system of accounting.

Maintenance embraces preventive work. The prevention of rusting by promptly painting either the entire span or the affected portions of it, the cleaning of dirt away from the shoes or bearing plates, the oiling of rollers, and the covering of floor-beams with boards, so that the brine-drippings from the refrigerator cars cannot strike the metal, are all examples of maintenance. Such prevention work, to be most effective, calls for frequent and regular inspections and a system of records that will enable the engineer in charge to know at all times the true condition of his structures without doing any guessing. Positive knowledge is needed as a basis for efficient maintenance. The cutting out and replacing of a rivet that has worked loose might also properly be included under maintenance; but the replacing of many such, or the adding of new stiffeners or cover plates to floor-beams or stringers, would come under the head of repairs. This could logically be extended to cover the replacing of the entire floor system or of a lateral system, while the taking

down of the trusses and remodeling them should come under the head of reconstruction.

To give the reader some idea of the various practical difficulties met with in maintaining and repairing bridges, the author offers the following information, which was furnished him through the courtesy of James MacMartin, Esq., C.E., Chief Engineer of the Delaware & Hudson Railway Company:

"Some of the Principal Troubles Met with in the Maintenance of Bridges.

"Bridge Bearings

"In a number of cases of bridges constructed before the general use of a pedestal and pin for the end bearing (other than for pin-connected spans) the masonry under the bearings has become loosened; and in some instances portions thereof have been broken off, due to the deflection of the trusses bringing a bearing upon the front edge of the supporting casting.

"In cases where track stringers rest directly upon the masonry, especially when the bridge is on a skew, the tendency is for the stringer bearing to work itself into the stonework, requiring the resurfacing of the stone and the use of additional plates to bring the track to grade.

"Where the fixed ends of some spans are on the abutment at the high end, when the structure is on a grade, cases have been found in which the bridge has pulled the abutment forward, owing to the rollers being small and not working as they should. A number of the older spans show signs of the bearing plates sliding on the rollers rather than the rollers turning. The use of pedestals with pins for bearings, adopting end floor-beams, increasing the size of rollers, and placing the latter on the abutment at the high end of the span have reduced the above defects to a minimum.

"Track Stringers

"In earlier designs, where I-beam stringers were used and the lower lateral bracing was connected to the bottom flanges of these beams, the holes through the stringers have been found cracked through to the outside of the metal; and, in some cases of end track stringers, the whole bottom flange has parted at this point. Where these I-beam stringers rest on the masonry the webs have been found cracked to a distance of three (3′) feet from the ends, and the said beams have been discovered to be so badly crystallized as to make it necessary to renew all the stringers in the bridge. We have eliminated the use of I-beam stringers from all but a very few of our bridges, and are doing away with them as rapidly as possible. We do not approve of the use of I-beams for floor-beams, stringers, or members subjected to tension; using them only for short spans over cattle passes and culverts. We have experienced none of the above mentioned troubles from the use of built sections.

"In some of our single-web, deck bridges some trouble has been experienced with the lower chord webs at the ends just in front of the bearings. Where there are no angles on top, the webs have cracked from the upper edge down to the bottom flange angles. This has been noticed also on some viaduct spans that were riveted to towers. Where angles are used on the top edge of the webs this defect has not been noticed.

"Rivets

"In cases where floor-beams rest directly on top of the lower chords in through bridges, and on top of the upper chords of deck bridges, a small percentage of the rivets connecting the floor-beams to the chords have been found loose; and we are constantly replacing such rivets. A few loose rivets are occasionally discovered in the connections of the web members to the chords. In cases of single-web bridges of

[illegible]

[illegible] in the later design. We find that

sides of the chords give good results, and that the

"On bridges where it is necessary to keep

with the paint in the vicinity of these barrels. Also

from the dripping of refrigerator cars, especially on our

only nine feet from centre to centre of girders, and, as

flange plates almost directly to the drip.

"Where abutments for deck bridges are built with a

have a tendency to collect around the bearings and

cases we have found the chords and the bottoms of end

dition occurs especially in deep trusses where it is difficult

seats. Extending the bridge seat for the full width of the

ing the recess entirely, removes this trouble to a great

"In girders where a cover plate the full width of the

was encountered due to dirt and cinders collecting in the

deal of attention from the track men to keep them clean.

narrow cover plates, where they are necessary, prevents the

in the chords. It is only in bridges of early design that

in use."

H. Ibsen, Esq., C. E., Bridge Engineer of the

road Company, sent the following:

"The principal trouble with the old bridges which we

course, that they have to carry a good deal heavier load

In the old deck, plate-girder bridges, the principal trouble

flange angles wearing loose at the ends of the girder. This

ting in additional rivets where the old spacing is such that

cannot, we have helped the matter somewhat by reaming

in larger rivets. The best remedy in cases of this kind is,

bridges; and we generally do this as soon as we can after

of overload in the manner described.

"In the old through-girder bridges with floor-beams and

loose in the floor connections, and the connection angles crack

this, we put in heavier connection angles and larger rivets.

"In the old pin-connected trusses some of the bars in the

often loose and wear badly on the pins. This is helped

bars of one member together. Bars also wear at the

main diagonals. This is helped by clamping the two

beam hangers have a tendency to work loose; this we

on check nuts where the thread is long enough to permit;

after adjusting.

"We have had trouble with the floor-beam webs showing

the ends when they are supported by hangers. We remedy

tional stiffening angles. We have had the same trouble with

mentioned in the through girders, and have remedied this in

"On our old drawbridges, we have had the same trouble

connections as in the pin-connected trusses; and we have

remedying it. These old drawbridges had no end lifts,

siderable hammering at the ends. This caused the rollers

also caused trouble with the track rails at the ends of the

have remedied by putting wedges at the end and sleeve

wheels over the joint in the rails at the ends of the bridge.

"With our new bridges, we have had no trouble except

On all open-floor bridges, both old and new, the drippings from refrigerator cars cause more trouble than anything else I know of. It is impossible to get any kind of paint that will protect them properly. Usually in bad places the paint will last less than a year on these bridges. In general, the damage is worst at the ends of the old bridges where they rest on masonry, as these bridges have no pedestals under the ends, so that the dirt easily collects around them, and the brine, together with the dirt, very rapidly corrodes the metal. The best remedy I have found with this class of bridges is putting a wooden board about 1″ thick in between the ties, so as to act as a trough to carry off the brine. There is, however, one trouble with this method, and that is that the dirt and cinders collect in these troughs, and it is expensive to keep them clean.

"The larger part of our new bridges are ballast-floor structures, consisting of I-beams with ⅜″ plate on top of same. With these bridges we have no trouble whatever, except that in some of the older ones the rivets in splices in the floor-plate work loose and cause the floor to leak at these places. This we have remedied by putting in additional rivets in the splices.

"We have had considerable trouble with our old stone masonry, such as abutments, piers, and arches, that are made of Joliet stone. This stone has cracked and spawled quite badly; but we have generally found that taking off the old copings and putting in new concrete ones will bind the abutments and piers well together, thus helping matters considerably."

Modern scientific designing has eliminated many of the defects so apparent in old structures; but familiarity with them will benefit the rising generation of engineers, as there are many old bridges still extant. Moreover, a perusal of the above statements will give them a better appreciation of the *raison d'être* of many of the clauses in the present-day specifications.

The engineer will at times be confronted with the question of the advisability of making extensive repairs, reconstructing the old bridge, or building anew. In deciding such a question, the guiding principle should be that of securing a minimum annual cost. In this the cost of repairs, or of the reconstruction, is to be considered in connection with the length of time that the same will be effective; and it must be remembered that such period of effectiveness is likely to be dependent upon the probable remaining life of the bridge itself rather than that of the repaired details *per se*. The annual cost is found by adding to the interest on the first cost any annual charges for maintenance, etc., and the annuity required to redeem the principal or a portion thereof in the allotted number of years.

Let S = first cost of new structure.

R = first cost of proposed repairs or reconstruction, plus the present salvage value of old structure.

n = the number of years that the repaired structure will be effective.

b_s and b_r = value of old materials in the new and the old structures, respectively, at the end of n years.

C_s and C_r = cost per annum, respectively, of maintaining the new structure and the repaired structure.

M = annual installment to provide a sinking fund to redeem one dollar at the end of n years at compound interest, as given

in Table 65*a*, which has been taken from Merriman's "American Civil Engineers' Pocket Book."

r = rate of compound interest.

Then $$M = \frac{r}{(1+r)^n - 1}.$$

Let A_s = "annual cost" of new structure.
A_r = "annual cost" of old structure repaired.
Then $A_s = Sr + C_s + M\ (S - b_s)$,
and $A_r = Rr + C_r + M\ (R - b_r)$.

TABLE 65*a*

Annual Installment Required to Accumulate One Dollar

(Installments Plus Interest Earnings)

Number of Years	Rates of Compound Interest						
	2%	2½%	3%	3½%	4%	4½%	5%
1...........	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
2...........	0.49505	0.49382	0.49261	0.49140	0.49020	0.48900	0.48780
3...........	0.32675	0.32514	0.32353	0.32193	0.32035	0.31877	0.31721
4...........	0.24262	0.24082	0.23902	0.23725	0.23550	0.23374	0.23201
5...........	0.19218	0.19025	0.18835	0.18648	0.18463	0.18279	0.18098
10...........	0.09133	0.08926	0.08723	0.08524	0.08329	0.08138	0.07950
15...........	0.05782	0.05577	0.05380	0.05183	0.04994	0.04811	0.04634
20...........	0.04116	0.03915	0.03722	0.03536	0.03356	0.03187	0.03024
25...........	0.03122	0.02928	0.02743	0.02567	0.02401	0.02244	0.02095
30...........	0.02465	0.02278	0.02102	0.01937	0.01783	0.01639	0.01505
35...........	0.02000	0.01821	0.01654	0.01499	0.01358	0.01227	0.01107
40...........	0.01655	0.01484	0.01326	0.01183	0.01052	0.00934	0.00828
45...........	0.01391	0.01226	0.01080	0.00945	0.00826	0.00720	0.00626
50...........	0.01182	0.01026	0.00886	0.00763	0.00655	0.00560	0.00478

A little reflection will show that it is necessary to take, for purposes of comparison, the life of the repaired structure as a basis for determining the annuities; for after the life of the repaired structure has elapsed it will have to be removed and a new structure built. Whereas, if the new structure had been built instead of repairing the old one, it would still have at the end of n years considerable remaining life and residual value. Hence it is sufficient to figure the "annual cost" of the amount of depreciation of the new structure for "n" years.

For the purpose of making the principle clearer, let us assume that an old structure having a salvage value of $500 can be made serviceable for ten more years (when its salvage will be $100) by expending $1,000 on it for repairs, and that a new structure replacing the old one would cost $2,000 and that it would last thirty years, but that it would gradually depreciate according to some law so that at the end of ten years it would be worth $1,700. Then the annuity must be such that the $300

of depreciation would be replaced at the end of the ten-year period. Rate of interest 5 per cent. Cost of maintenance of old structure 1.5 per cent per annum and of new structure 1 per cent per annum. The annual cost of new structure, for purposes of comparison, becomes

$$A_s = (.05 \times 2{,}000) + 20 + (.0795 \times 300) = \$143.85,$$

while the annual cost of the old structure becomes

$$A_r = (.05 \times 1{,}500) + 22.5 + (.0795 \times 1{,}400) = \$208.80.$$

In this case it would be better to sell the old structure for the $500 and apply it on the cost of the new one.

If the original salvage value of the old structure be neglected, the annual cost would then become

$$A_r = (.05 \times 1{,}000) + 22.5 + (.07950 \times 1{,}000) = \$152.00,$$

which still leaves the new structure the more economical of the two. Generally speaking, if the use of a Hibernianism be permissible, the easiest, most economical, and satisfactory way to repair an old bridge is to tear it down and build a new one.

Observation shows that depreciation proceeds slowly at first and becomes more rapid as time advances and as the loading increases. It is not practicable to state the law that governs the physical processes of deterioration, if, perchance, such a law exists. The eminent bridge specialist, J. C. Bland, Esq., C.E., Bridge Engineer of the Pennsylvania Railroad System, has studied deeply into this question; and in his tentative investigation, which he had to make with most insufficient data, he suggested three methods, two of which he declared to be faulty, and the third only approximately satisfactory. His method, reduced to mathematical form, may be given by the equation,

$$D = \frac{(1 + i)^x - 1}{(1 + i)^n - 1},$$

where D = the proportional depreciation at the end of x years,
i = rate of interest expressed in hundredths,
n = total number of years of useful life of the structure,
and x = number of years at which the depreciation is figured.

This formula was established by analogy, and no claim is made for its correctness.

The author is of the opinion, however, that the depreciation will vary more nearly according to the ordinates of a parabolic curve, which is expressed by the formula.

$$D = ax^2.$$

[illegible]

If $x = n$, D will equal unity, and

$$1 = an^2, \quad \text{or} \quad a = \frac{1}{n^2}$$

and

$$D = \frac{x^2}{n^2}$$

This is more simple than the preceding formula to be correct; for the more deteriorated a bridge be is its rate of deterioration, and toward the end of certainly depreciates very rapidly. Truth to tell, *of deterioration;* for the steelwork of a properly de factured, properly constructed, and properly pr *deteriorate at all,* unless the live load be increased limit; and for such a structure if the up-keep be only the deterioration by rusting will be slow; but it is more rusted the metal is the more rapidly the oxid hence it is fair to assume that, as far as deterioration by the rate will vary as the square of the life.

In case it is decided to repair or reconstruct step to take is to form a plan for so doing. If the strengthened, the stringers may be doubled up, cov eted to the flanges of the floor-beams, and additional inserted at points of concentrated loading. This was the St. Louis and San Francisco Railway Company's This sort of repairing generally pays, as the trusses load while the floor system does so quite often. Falsework for repairs of this nature; and the placing of the new ally be arranged for between trains so as not to inter

Where plate girder spans are to be strengthened, process is practicable and not expensive; and it inter any, with the regular train service. At times old trus placed to material advantage by inserting one or two the old ones and substituting plate girders for the trusses scheme, providing the waterway will permit of such tion and that the Government raises no objections. followed to a large extent by the author in reconstruct for the International and Great Northern Railway and in rebuilding the Black Hawk Chute portion Railway Company's Mississippi River Bridge at Keith instances many of the piers had to be remodeled by and the upper courses of masonry and rebuilding obtain a larger top. The old spans had to be sup close to the piers while the tops of the latter were

When old truss spans are to be replaced, the dif

[illegible] similar to that used by bridge [illegible] Then the metal should be taken down and piled [illegible] for subsequent shipment.

[illegible] a chord section or web member, it will [illegible] under the span in order to support it [illegible] period of repairs. Lateral systems can be [illegible] without special difficulty. The replacement of [illegible] the lateral system with rigid sections is desira[illegible] expensive; and this change should be made [illegible] railway structures. As shown in Chapter LX[illegible] to keep an old bridge open for traffic while [illegible] the old piers. In such a case the new spans [illegible] the old. Falsework is constructed under [illegible] of sufficient extra width to accommodate th[illegible] have to carry the live load in addition to the [illegible] The trusses and the upper laterals are erected, then [illegible] dismantled, one piece at a time, the old floor-beams [illegible] new ones are set in and connected to the new trusses. [illegible] are replaced, one at a time, by the new ones; and, [illegible] laterals are set in and riveted up, after which the false- [illegible] The carrying of the new metal by the old span [illegible] replacement is sometimes done. See the account [illegible] reconstruction in Chapter LXIII.

[illegible] reconstruction of substructure, especially below the [illegible] with more difficulty than is that of the superstruc- [illegible] necessary to enlarge the tops of old piers in order [illegible] It is then essential to support the adjacent spans [illegible] constructed close to and on each side of the pier. [illegible] necessary of the top of the old pier is taken off, and [illegible] vertical faces is built on, thus providing a larger [illegible] A further increase can be had by constructing a [illegible] under the coping. If additional strength is required, [illegible] should be buried in the new top in order to distribute [illegible] the loads over the mass of the pier. Before plac- [illegible] holes and crevices in the old masonry should be filled [illegible] grout. The joints and beds of the masonry courses [illegible] loose mortar dug out and new mortar rammed into [illegible] If the old masonry show signs of disintegration, [illegible] by removing all the loose material and thor- [illegible] stonework and saturating it with a stream of water. [illegible] should be filled with either Portland cement mor- [illegible] after which a wire netting is to be stretched around [illegible] thereto with spikes. A final coating of mor- [illegible] cement gun. This method was successfully em- [illegible] abutments of the Chicago & Western Indiana

cal piers can be
around them, pumping out the water
to the foundation, and building a
foundation. In the case that it is not practic
with the new excavation, piles may be driv
the old pier and the cofferdam and
around the old construction.

In the case of weak foundations, or an
timbers in grillage or in cribs, when it
the base of a pier in order to effect the
can be sunk around the old pier, leaving
the two for workroom. Of course, the crib
would have to be extended up at least to the river
would have to be built on top of that sufficient
flooding of the inner space. After sealing the
between it and the old pier is to be excavated to the
the underpinning operations may proceed, or, if
old base may be left intact and the excavated
thereby securing an augmented bearing area and a
concrete reinforcement can be carried to any desired
a portion of the load is effectively transferred to it
increased area of base will not relieve the intensity
foundation. An excellent example of this method
given in Vol. LXXIX of the *Transactions* of the
Engineers for November, 1914, the case cited being
Junction Bridge at Little Rock, Arkansas, owned by
Mountain, and Southern Railway Company. In this
not located accurately, being two or three feet off
eccentric loading, and the timber crib above the caisson
with sand instead of riprap. As the sand leaked out,
was thrown on the timbers, and a crushing and
occurred shortly after the completion of the bridge,
slowly thereafter until repairs were made fifteen years
uable lessons can be learned by a careful reading of the
paper. Among them are that timber cribs should
concrete, that caissons should be sunk with greater
should be large enough to admit of some shifting of
in order that it may be built in exact position,
have more than a bare sufficiency of area under
the shoes of the spans, that some logical method
should be employed on every job that will fix
protection of the resident engineer and his
neer, lies in going on record in an effective way

[illegible] with the [illegible]

[illegible] was retained as consulting [illegible]
[illegible] Bridge at Ft. Leavenworth, K[illegible]
[illegible] by fire. The bonds of the bridge [illegible]
[illegible] the Dutch bankers interested decided to [illegible]
They sent over a Dutch engineer to take [illegible]
[illegible] not a bridge specialist, the author was [illegible]
[illegible] specifications for the repairs and to [illegible]
[illegible] The structure was a high bridge, [illegible]
[illegible] that rested on high, cast-iron, cylinder [illegible]
[illegible] The superstructure detailing was so [illegible]
[illegible] chords were so cracked that many change[illegible]
[illegible] be made in order to repair dangerous flaws [illegible]
[illegible] high intensities of working stress[illegible]
[illegible] The work cost a little over one hundred
[illegible] was a large sum for repairs, considering that the
[illegible] six hundred thousand dollars, that the income
[illegible] and that the probable life of the structure was
[illegible] Had the calculations described earlier in this
[illegible] probable that the bankers would have saved their
[illegible] the structure to its fate. After some ten years of
[illegible] Railway Company, its employment for railway
[illegible] discontinued, and as the income from the [illegible]
[illegible] it was soon afterward closed to traffic entirely.
[illegible] approaches a mass of rusting iron that some day
[illegible] navigation of the river.

[illegible] chapter the author desires to express his thanks
[illegible] Ibsen, and Bland for their courtesy in furnishing
[illegible] information herein quoted.

CHAPTER LXVI

STATUS OF HIGHWAY BRIDGES

For nearly half a century the designing,
highway bridges have been synonymous with
graft; and it is only lately that there has appeared
tainment any genuine improvement in the highway
the old days of wooden bridges, when little or no
theory of stresses or the principles of design, high
much more substantially and honestly; for then
used was cheap, and designers made a practice of
by an extravagant use of it and by employing in
of cancellation, having their members connected
at every intersection. Again, in those days bridg
upon as an art, and the building of a bridge was con
ment, consequently bridge construction was attemp
skilful carpenters; and those men, having but littl
took a pride in their work and built their struct
tecting them at great expense against the destructi
snow by housing them in on top and sides. The
made the bridges so heavy that vibration was chec
results of impact were reduced to a minimum; and
of intersection employed so divided the stresses
any member or connection that had a tendency to be
consequence of these facts was that the bridges thus
scientific and uneconomic in the extreme, lasted a
today some of them still exist and serve as a mon
and skill of their builders, who have long since pass

But with the advent of iron bridges came a know
tribution and the custom of proportioning each
for the computed theoretical static stress upon it,
given to the effect of impact, and no real attenti
connecting details. The accumulation of book know
times consisted essentially of theory, caused the pub
awe and respect upon the art of bridge building; and
unskilled workmen but also mere bookworms began
too, could build bridges. The result was a great
of bridge builders, keen competition for contracts,
structures with a more than corresponding redu
proportioning solely to comply with set requirem

ally fixed by ignorant commissioners or equally ignorant county surveyors), ignoring of all considerations of rigidity, adoption of extremely light live loads, and, in short, skinning the design and cheapening the construction in every possible manner in order to secure contracts. The effect of this condition of affairs was soon evident, for highway bridge disasters quickly became common, and bridges comparatively new had to be replaced because of glaringly evident weaknesses too difficult to correct. The road roller and the traction engine began to get in their deadly work, and metal structures over railways commenced to fail from corrosion, because of the cheap paint used and the thin sections adopted. Such structures have been rightly named "tin bridges," and their builders have appropriately been dubbed "highwaymen." Indeed, in one sense they are worse, for highwaymen usually demand "your money or your life," while these bridge builders do their best to take both! Their object is invariably to obtain the maximum amount of money for the miminum amount of bridge, and to succeed therein they often find it advisable to "stand in" with the county commissioners. That such "standing in" is not unusual is proved by the following amusing anecdote told by the late C. E. H. Campbell, a well known western bridge contractor, in the columns of *Engineering News:*

> "A certain bridge company sent its agent to bid on a large highway bridge. The agent found strong odds against him and wrote his superiors for advice. The company wrote back that a proper amount of 'the long green' judiciously placed where the proper officials would find it, would do more toward securing the contract than all the chin music that he could grind out. Unfortunately (?) the agent lost the letter of advice. It was found by the agent of a rival concern, who immediately had several hundred copies printed and distributed all over the country so as to warn the 'unsuspecting agriculturalists' (who filled the county offices) against those bad persons, and thereby run them out of the business; but, strange to relate, an unprecedented wave of prosperity soon overtook the bad company, and for several years afterward they did a thriving business, often obtaining contracts at higher prices for lighter work than their rivals, and they still continue business at the old stand, over-reaching all competitors."

Soon after the advent of iron bridges, pooling of competitors became an established custom, and this so multiplied the number of bidders that their name became legion. All that a bridge agent or scalper needed in order to obtain his "rake-off" was a bundle of old drawings, some printed forms to fill out, and unlimited assurance. Many amusing stories are told of bridge lettings and of the devious ways of the competitors, a number of which have found their way into print. Here is one that has not:

Some years ago half a dozen "highwaymen" met on a railway train, which they had taken to attend a bridge letting, and there formed a pool with a good commission for each. Mr. T., another "highwayman" and a past master in the art of securing contracts, happened to be in the same train on his way to New York. He knew nothing of the letting, but seeing six of his usual competitors in one of the coaches, he went to his berth

[illegible] They concluded that [illegible] would be broken, consequently [illegible] to approach Mr. T. and offer him [illegible] from the letting. He went to the [illegible] asked him where he was going, to which [illegible] of you fellows," and pointed to his [illegible] his offer, to which T. replied, "not for [illegible] dollars, and cash down at that." After [illegible] the delegate returned to the rest, the [illegible] (for highway bridge agents and scalpers [illegible] their travels to be well provided with cash), [illegible] over to T., who went on his way rejoicing. [illegible]

Another amusing story that the author [illegible] ignorance and worse of the professional "highway [illegible] of them who operated in the northwest had [illegible] him a diagram of stresses and sections for a light [illegible] way bridge; and he used it several times to good [illegible] tracts. On one occasion, having to bid on a [illegible] submitted the same sheet, secured the contract, [illegible] to the little manufacturing company which furnished [illegible] for his superstructures, and obtained the material [illegible] being offered. Having been so successful in this [illegible] the scheme again with a one-hundred-foot span, [illegible] Thus encouraged, he gradually increased the span [illegible] the diagram serve until he reached one hundred [illegible] the manufacturing company wrote him about the [illegible]

"You have already stretched that old stress [illegible] elastic limit, and we refuse to be a party to any further [illegible]

Pooling is illegal, and in some states it is a criminal [illegible] able with both heavy fine and imprisonment; never [illegible] in the highway bridge business; and as long as [illegible] ducted in the manner still in vogue, just so long [illegible] continue. County commissioners are themselves to [illegible] state of affairs; because they make a practice of [illegible] upon competitive plans, and thus attract a huge crowd [illegible] letting, putting each competitor to considerable [illegible] traveling but also occasionally for preparing de[illegible] taught the competitors that there is seldom any [illegible] bid, and that it is one of the men on the ground [illegible] secures the contract. All traveling and bidding [illegible] to be paid by somebody, because "highwaymen" [illegible]

bursement for their unavoidable
arrange for each bidder to add to his
ally for each occasion, to cover the legitimate
proved so easy that soon the amount was increased
profit, and ere long it was made as large as the job
often it contained money to be used for corrupting
long before these conditions rendered the building
highway bridges almost impracticable; for, no matter
the county was willing to spend on a structure, the
and would build the cheapest bridge they dared,
for commissions to unsuccessful (?) bidders, large
and "parliamentary" expenses. Moreover, it is an
established custom that highway bridge builders
and construct good bridges, even if they so de-
first place, they were densely ignorant of the enor-
transgressions against good engineering practice
generally being considered right); and, in the second
status and constructive ability of highway bridge
had been so lowered by the influx of scalpers at
the moral sense of the craft was pretty nearly
This sad state of affairs continued to exist for many
occasional vigorous attacks upon it and urgent
engineering writers, among others the author. These
some good in a few cases, but their general effect
it is only the strong arm of the law that can put
and remove menaces to the lives of the people. High-
year after year have been almost of weekly occur-
they have involved the loss of human life. Some
made to legislate against the building of unsafe
in most cases these have been failures.

way to put down the abuse and to stamp out the
in bridge construction is to have the various states
competent bridge engineers to prepare plans
all highway bridges and to supervise their manu-
; and to make it a crime punishable with im-
such structures in any but the manner prescribed
of maintaining a state bridge engineering force
because standard plans for both substructure
be prepared; and these would be used in nine
appointing of the State Bridge Engineer and his
left in the hands of politicians, but the Governor
select only from a list of applicants endorsed by
Civil Engineers; and that society should give
a thorough examination of each applicant

on both theory and practice by a
from its members.

The advent of the reinforced concrete
inauguration of a better state of affairs in
and the means of correcting the crying evils
long. Counties that are tired of replacing
bridges" are beginning to call for reinforced
these require very little annual expenditure for
and, as far as is known at present, when
they will last practically forever. But the same
and the same criminality in building that for decades
of the metal bridge business are becoming the
construction. It requires engineering skill of a
practical experience to plan bridges of reinforced
to design steel structures, and the former need
tion of materials and workmanship than the latter.
are as follows:

First. The building of reinforced concrete
is only beginning to be systematized.

Second. Concrete bridges are an eminently
for some locations, but for others they are
used in the wrong places they are liable to involve

Third. It is just as easy to skin the life out of
of a concrete bridge as it has been in the past to
of steel bridges below the danger limit; in fact, it is
the deed is once done, all proof of it is hidden
disaster has overtaken the structure.

Fourth. The prevention of the use of improper
crete throughout the entire construction is a very
a barrel or two of inert cement worked into a critical
in the destruction of the bridge. When one span
bridge collapses the others are more than likely to
structure from abutment to abutment falling down
because the piers are generally incapable of resisting
from the dead load of a single span. To make them
would involve an expenditure of money that is
dead load thrust of any span should be resisted by
ing spans, except at the ends of the bridge, where
the massive abutments.

Fifth. The safety of a reinforced concrete
dent upon a proper proportion of ingredients in
ough mixing of them, and therefore it is at the
subject to the vigilance and care of the foremen
practicing of that all too common and most
cement in order to reduce the cost of construction

serious consequences in a reinforced concrete arch bridge than in the piers for a steel structure.

If county commissioners will have the good sense to consult competent bridge engineers before deciding to build reinforced concrete bridges, will retain them to make the plans and specifications and to supervise the construction, and will pay them upon a sufficiently liberal basis to permit of their hiring all the good inspectors that the work needs, they will succeed in effecting a great improvement in highway bridge building. But, alas! this is too much to expect from ordinary county commissioners, who are too often chosen from the ignorant classes for political and other improper reasons; hence it is to be feared that the highwaymen, the scalpers, and the unfit designers will continue to get in their nefarious work, and that reinforced concrete structures will prove no more reliable or durable than the notorious "tin bridges."

Since the preceding was written the author has received a letter from his friend, J. C. Ralston, Esq., C. E., formerly City Engineer of Spokane, Wash., from which, with the writer's permission, the following extract is made. It confirms very effectively the preceding anticipation of future disaster to reinforced concrete bridges designed by incompetent or improperly interested parties. Speaking of a certain highway bridge builder, Mr. Ralston says as follows:

> "He is the man who designed and once put forward seriously an arch made of an intrados ring of concrete about four (4) inches thick and an extrados ring of the same thickness, the two rings being separated about twelve (12) or sixteen (16) inches, and this interior filled with a well-rammed, nice, juicy clay. This, of course, furnished an ample play-ground for the neutral axis and the lines of pressure to play hide-and-seek, besides offering special plastic inducements for these frisky functions to stay at home. In fact, I surmise that such a design, in the opinion of the designer, circumscribed their sphere of action within the middle third by barriers of actual concrete. Thus we reach the superlative—the very acme of perfect design, when by such simple mechanical means we confine all such ill-bred functions to an argillaceous field of innocuous desuetude. Need we congratulate ourselves on being members of a profession in which its great leaders weave in such epoch making fashion the dulcet lines of theory and practice into an incomparable fabric of royal perfection?"

But, seriously speaking once more, the reinforced concrete bridge, which certainly has come to stay, is eventually going to prove the cure for the ills of highway bridge building, and the medicine that will effect it is the motor truck. That type of traffic-vehicle has proved itself to be economic, and it has rapidly become heavier, until now its loads rival those of the famous road-roller—that bugbear of highway bridge builders. Furthermore, it must be remembered that the road-rollers traverse bridges so slowly that their impact is assumed to be zero, while the motor trucks pass over at speed, necessitating the usual highway impact allowance; hence in designing the floor systems it will nearly always be found that the motor truck is the ruling factor. The ordinary county bridge of steel trusses with wooden floor is so lacking in strength, rigidity, and mass as

[illegible] vehicles have no restricted area of ope[illegible]

[illegible] country districts is rapidly increasing [illegible]

[illegible] tracks and the bridges will soon [illegible]

[illegible] be relegated to oblivion. [illegible]

CHAPTER LXVII

BRIDGE FAILURES AND THEIR LESSONS

The scope of this chapter does not permit of an enumeration of all the railway bridge failures that have occurred since structural designing was placed on a rational basis by Squire Whipple; nor has the author available the necessary statistics for making such a compilation. However, it is desirable that the reader should have an appreciation of the influence that past failures have exerted in advancing the standard of bridge designing and construction and in hastening the adoption of the bridge specialist's recommendations. To the newer generation of engineers, it might seem that the present excellence of bridge design and construction has been attained without much effort. Such, however, is not the case; for the present standard has been reached by a costly weeding-out process—the defects being brought to light by failures of structures or of parts thereof. It has cost a great many lives and dollars to attain the present standard of excellence. The mental inertia of those in authority which had to be overcome was enormous. Improvement has been brought about through the persistent efforts of the consulting bridge engineer by raising the requirements in his specifications so as to keep pace with the acquisition of new facts, and through his insistence that the said specifications be adhered to.

There is always something to be learned from a failure; but too often failures are smoothed over and minimized and given insufficient publicity, so that their lessons are not duly observed nor appreciated. That there have been numerous failures in times past one can readily see by glancing through the back numbers of the engineering periodicals. For instance, the *Engineering News*, Vol. 23, page 373, gives the following table of railway bridge failures covering the period of years from 1879 to 1889, inclusive.

TABLE 67*a*

Bridge Failures from 1879 to 1889

	1879	1880	1881	1882	1883	1884
Bridge failures, iron	3	1	4	6	2	
Total	16	10	38	34	27	33
Miles of track, Jan. 1, each year, 1 = 1,000	81.8	86.6	98.3	103.1	114.7	121.5
Miles per bridge failure	5,110	8,660	2,450	3,030	4,250	3,675

TABLE 67*a*—Continued

	[illegible]	[illegible]
Bridge failures, iron	1	8
Totals	25	20
Miles of track, Jan. 1, each year, 1 = 1,000	125.4	128.3
Miles per bridge failure	5,016	6,415

This table shows a total of 286 failures in eleven
of twenty-six per annum. Forty-three of these
bridges, an average of nearly four per annum. The
and persons injured in the eleven-year period is not
year 1889. there were reported nineteen deaths and
injured in twenty-two wrecks of bridges. In 1889, the
period, there were some 24,450 iron spans and 15,250
service; and of these, five iron spans and seventeen
Four of these iron spans which succumbed were
cars and one by a defective pier. Of the wooden-
structures were burned; three were wrecked by freshets,
down by derailed cars, and three succumbed from inherent

In many cases impact due to derailment of cars
Lack of precaution at the ends of the structures in the
re-railing frogs, and collision posts was a contributing
these accidents. Hence it is reasonable to conclude
might have been prevented and the effects of others
remark applies to the cases of the burned wooden bridges
out by freshets. In 1895 there were thirty-seven failures
causing a loss of fifty-seven lives, besides injuring eighty-
teen of these structures were knocked down, five were
were destroyed by fire, and five were carried out by
these thirty-seven failures were of iron or steel bridges,
knocked down and one wrecked by a freshet. Six electric
failed that year, resulting in forty-six persons killed
Further details concerning these failures will be found
News, Vol. 37, page 93. It will be observed that the
an increase in failures over that of 1889, which, perhaps,
as the number of bridges had increased considerably.
improvements had been made in design and construction,
vices had been developed, so that if the railroad
themselves of these things to a larger extent, this
have been reduced. However, as fourteen spans were
ment, six were burned, five failed because of inherent
part, and five were washed out by freshets, it seems
earlier failures had not been heeded. Moreover,
given by the technical press to these accidents at

cases given in the list above quoted from the
mentioned in the *Engineering News*, *Engineer-*
Gazette. They were probably considered as of
hence were ignored; but one hundred and three
are certainly of great importance, because that is a
the repetition of lessons which should have been learned
price paid by the public, not for its own blunders,
edness of railroad authorities who were seeking to
profit from that public. Yet such is the inertia of the
innovations are usually spurned by the majority without
and it takes a repetition of impulses to produce action.

not at hand the statistics for later years and, there-
to say whether the number of failures is increasing out
number of bridges in service. However, as a newer
is coming into responsible charge of work, he feels
of some of the more serious failures of past years will
Those failures occurring before the establishment
design by Squire Whipple will not be considered.

failures was that of the railroad bridge over the Gas-
Missouri. This was of such serious import that the
Railroad appointed a committee to investigate
accident and report thereon. This report, which was
on November 19, 1855, gives as reasons for the fail-
and too great speed of train. The design was at
adequate sections for the stresses to be resisted.

bridge disaster was that at Janesville, Ohio, in 1866.
the accident was dated at Detroit, Mich., Decem-
gives the cause of the failure as the "weakness of
beams"—another case of faulty design in detail-
Bridge failed in December, 1876, causing ninety-
four injuries. Failure occurred in the top chord of
diately under the driving wheels of the locomotive
or 22 feet, from the abutment. This structure
Howe-truss bridge, with cast-iron top chords, and
old at time of the accident. In addition to the
cost the railroad company fully $600,000. This
donment of cast iron for principal parts in future

bridge over the Missouri River at St. Charles, Mo.,
derailed car or truck, producing through impact
in certain members, some of which were of cast
dent occurred in 1887 on the Dedham branch
Railroad, five miles from its terminus in
hangers supporting a floor-beam next to
floor system settle so that the cars follow-

[illegible]
[illegible]
and they had old [illegible] which had not [illegible]
bridge inspector, who, instead of being a [illegible]
The Engineering *News*, Vol. 27, pages 180, [illegible]
detailed account and discussion of this failure. [illegible]

The collapsing of the Atchison, Topeka, and [illegible]
across the Pecos River in 1892 was due to the [illegible]
ment and not to any defect in the span. A [illegible]
an unusually heavy rain-storm raised the [illegible]
normal height and to within three feet of the [illegible]
site the river made a sharp turn, forming an eddy [illegible]
undermining the abutment and causing it to tilt [illegible]
movement became sufficient to allow the end [illegible]
masonry, the weight of the bridge was thrown [illegible]
the first panel. These tore loose and were raised [illegible]
lower chord were badly bent. Soundings made [illegible]
a smooth flat bed-rock eight feet below water, [illegible]
the rail. That this opportunity for securing a safe [illegible]
looked indicates gross carelessness.

Another instance of substructure failure is that [illegible]
piers of the Little Rock Junction Bridge of the [illegible]
Railroad Company at Little Rock, Ark. These [illegible]
about 1884, but so poorly that trouble was [illegible]
the very start; and efforts have been made during [illegible]
to correct the defects resulting from the contract [illegible]
largely with sand instead of the stone called for in [illegible]
cations. This sand leaked out, and the small [illegible]
was used settled through the crib, leaving the [illegible]
the load unaided. These timbers were not sufficient [illegible]
burden, and hence were crushed. This condition [illegible]
fact that the location of the piers was badly done, [illegible]
from two to three feet off centres when finally placed [illegible]
necessitated the building of the shafts of the piers [illegible]
to conform with the span-lengths, thereby placing [illegible]
the cribs and caissons. Unequal settlement and [illegible]
the shoes of some of the spans overhung the edge [illegible]
pending disaster was narrowly averted from time to [illegible]
and placing I-beam grillage under the shoes. In [illegible]
pairs were undertaken, and annular caissons surrounding [illegible]
defective piers were sunk to bed-rock. The space [illegible]
the old and the new caissons was partially [illegible]
concrete. This was an effective expedient for [illegible]
in position, but the movement of Pier 4 was not [illegible]
pier had moved so far that one of the spans [illegible]

[illegible]

[illegible] bent was constructed to [illegible]
[illegible] The bearing for this bent [illegible]
[illegible] footing on the wide edge of the [illegible]
[illegible] account of this and further repairs is given by
[illegible] in Vol. LXXIX of the *Transactions* of the [illegible]
[illegible] Engineers. The lesson to be learned from this
[illegible] work is that it is both safer and less expensive to the
[illegible] in preparing substructure plans and to see that
[illegible] out the essentials of the said plans before he gets
[illegible]

[illegible] a bridge on the Boston and Albany Railroad at
[illegible] way while a through vestibuled train was passing
[illegible] several of the cars into the river. The bridge was
[illegible] and the rivets had been cut out of the top chord of
[illegible] a length of about ten feet. The additional plates
[illegible] not riveted when twelve o'clock came and the work-
[illegible] the foreman having left the work a half hour earlier.
[illegible] carelessness seventeen persons were killed and over
[illegible] Another serious accident occurred during the same year
[illegible] Jeffersonville Bridge across the Ohio River at Louis-
[illegible] being then in process of erection. One of the
[illegible] completed and its falsework removed, but the lower
[illegible] placed in the two panels at the south end; while
[illegible] span was partially assembled on falsework. On De-
[illegible] strong wind caught the traveller, while the guy ropes
[illegible] to moving it, and tilted it so that its load
[illegible] was thrown on one corner for support. This was
[illegible] bent of the falsework, which had previously been
[illegible] by the scouring of the river bed. The failure of this
[illegible] caused the rest of it and the partially erected
[illegible] so that practically the entire span was lost. Later
[illegible] span above mentioned failed and dropped into
[illegible] wind storm. This span was 550 feet long and
[illegible] pounds, which precludes the possibility of its
[illegible] blown off the piers, because the surfaces exposed
[illegible] those of the chords, web members, floor system,
[illegible] The probable cause of this failure was reported by
[illegible] bolting up of the splices in the inclined
[illegible] inability of the latter to resist the bending
[illegible] wind load; but the author is of the opinion
[illegible] was the omission of the lateral diagonals of the
[illegible] the span. Without these there was no way
[illegible] the lower lateral system to the pier, because,
[illegible] and the hip verticals being of eyebars

only, it could not travel to the hips by
by the portal bracing to the pier. The
the span was free from the falsework was
worst possible description; for this accident
twenty lives.

An instance of a failure of a bridge due to the
that of the New York and Ottawa Railroad Company
American channel of the St. Lawrence River near
Fifteen men were killed in the accident, and
jured. The erection of the two adjacent spans
been completed. The falsework under one had
traveler was being dismantled on the other at the
The river at the site of the pier is about thirty-five
swift current estimated to run from five to eight
river bottom is a clay hard-pan in which boulders are
them being of large size. No borings were made
mine the thickness of the hard-pan and what material
pier was founded by sinking a timber crib and
deposited under water by buckets dumping at the
concrete was placed, divers went down inside of the
samples of the bottom, which were deemed satisfactory
The first concrete laid was put in sacks and deposited
of the crib, after which the remainder was placed by
carried up to a plane four feet below water level.
pumped dry, and two courses of masonry were set.
pier went through the winter season and successfully
ice pressures; and in the spring it was struck by a
was broken by the collision, but the pier showed no
Shortly afterward the remainder of the shaft was
erection of superstructure was begun. The pier was
with the current and had no riprap about it to
obliquity and some restriction of channel by the
piers produced an increase in velocity sufficient to
the pier on one side, so that it toppled over without
two adjacent spans fall into the river. After the
made to determine the nature of the foundation.
that the hard-pan was only from eighteen inches
below that, for a depth varying from twelve to
or clay. This, of course, should have been
for the substructure were prepared. The fact that
renders those in responsible charge guilty of
makes them accessories to the deaths of the
plans were made under the direction of the Chief
York and Ottawa Railway Company, were
Engineer of that company, and were further

Government engineers without the basic information relative to foundation material—passes understanding. The general fact that glacial drift is extant in all that part of the continent should have aroused the suspicions of the designer and led him to insist on borings being made in order to obtain correct data.

The Erie Railroad Bridge at Buchanan Junction, a few miles from Meadville, Pa., was wrecked in October, 1902. The structure consisted of one central truss span and two half-through, plate-girder spans. At the time of the failure a freight train had partly crossed the bridge. The evidence indicated that one of the posts of the north truss had been hit by a plate-girder floor-beam in transit, projecting from a flat car upon which the load had shifted. This floor-beam jammed against the car behind with sufficient force to break the train in two. The shock of the blow and the momentum of the train behind were sufficient to buckle the post, causing that side of the bridge to drop and to pull the other side down with it. This accident was not due to any defect of the structure.

A suspension bridge at Charleston, W. Va., gave way under a load consisting of a layer of snow and ice four inches thick, twelve teams, and about fifty pedestrians. Two of these were killed outright and others were more or less seriously injured. The primary cause of this failure was an impairment due to the fact that a high water previously rose over the floor at one end, which was at a lower elevation than the other. The pressure of the current caused the bridge to tilt at a considerable angle, which condition produced an excessive loading on the up-stream cable, snapping some of its wires and weakening it so that later it failed. After the water receded, the floor returned to its normal position with many of the wires broken, but it was still used by the traveling public until the time of the accident. Above ground the cables were found by subsequent investigation to be in a much better condition, because of painting, than under the stonework where they were subjected to frequent wettings and had become badly rusted. Many of the wires in the interior of the cables were eaten entirely through. Six years before the failure, the bridge was known to be in a dangerous condition; and several times it was closed to traffic, but after temporary repairs was reopened. The cables that failed were enclosed in anchor masonry, and hence could not be inspected. The lesson to be gained from this case is that the important parts of a bridge should be built so that they may readily be inspected at all times, and that a bridge known to be in a dangerous condition should be replaced by a new structure without delay.

The most stupendous failure on record is that of the Quebec Bridge across the St. Lawrence River, the accident occurring during erection on August 29, 1907. The collapse came suddenly and without appreciable warning to the eighty-five men on the structure. Only eleven of these were rescued, and all of them were more or less seriously injured. This bridge was the longest of its kind that had ever been attempted in any

land, and it was supposed to represent the best product of the bridge builder's art at that time. The fall was due to the buckling of the lower chords of one of the anchor arms. The chord sections consisted of four thick compound webs, with comparatively very small flange angles held together by lacing angles. Each web was made up of four plates aggregating a thickness of 3½″ and angles for flanges at the sides for lattice connection. The dimensions of the chord section were 4′ 6⅝″ × 5′ 7½″. The lattice angles were 4″ × 3″ × ⅜″ and the cross struts 3½″ × 3″ × ⅜″ angles. The insufficiency of this lacing and the lack of stiffening in the flanges of the separate ribs, or webs, were the defects that permitted the chord sections to buckle. This, of course, was faulty designing; but later the designers claimed that there were no precedents for proportioning compression members of that magnitude. However, it was even then generally recognized that in designing all struts the principal radii of gyration should be made as great as possible, and that there should be, in general, some equality of division of the metal between webs and flanges. No reliable theory had then established for proportioning lacing, nor were there any recorded results of tests made on such details for large members. Another contributing cause was the existence of a dead load thirty (30) per cent larger than the bridge company's designing engineer had assumed when making the stress calculations.

The Canadian Government appointed a commission of able engineers to investigate and report on the causes of this failure. An abstract of their report will be found in the *Engineering News*, Vol. LIX, pages 307 and 317.

The lessons to be drawn from this awful disaster are as follows:

First. A consulting engineer should never trust the detailing of a bridge to the manufacturing company, but should prepare complete plans therefor in his own office.

Second. It pays to spread the metal in compression members as much as is consistent with other features of good designing.

Third. There is no excuse for the actual dead load in any bridge exceeding that assumed by more than a mere trifle.

Fourth. One should heed warnings even when they come from uneducated workmen.

Fifth. Plenty of time should always be allowed for making the preliminary studies for a design and the working plans.

Sixth. It is exceedingly bad practice to skin the life out of a bridge in order to save metal.

Seventh. In every important bridge project the completed plans should be checked in detail throughout by some capable bridge engineer who is entirely disconnected from either the consulting engineer or the contractor.

This terrible accident to the first Quebec bridge was a most severe blow to the entire bridge engineering profession in America; for it will be many decades before the European engineers cease taunting their

[illegible] country about the failure and its [illegible] bridge specialist of any prominence is there [illegible] has not felt more than once the evil effects on his [illegible] lack of skill and attention which was char-[illegible] and building of that ill-fated structure.

[illegible] chapter the failures of highway bridges have [illegible] their name is legion. So many cases have resulted [illegible] and dishonesty on the part of both designers and [illegible] hardly worth while to pick out a few specific cases. [illegible] realize the need of engaging the services of an out-[illegible] specialist, such disasters will continue.

[illegible] examples of railway bridge failures are but a few se-[illegible] random out of the many that are on record. These [illegible] things to contemplate, but a careful study of them leads [illegible] increased knowledge, improved methods, and a keener [illegible] the responsibility resting on the engineer. In general, [illegible] resulted from faulty design, inferior workmanship, poor [illegible] treatment. To reduce these factors to a minimum is [illegible] conscientious engineer, but too often the anxiety of [illegible] something done in a hurry or too cheaply is the underlying [illegible]

[illegible] will come with fuller knowledge, better workmanship [illegible] supervision, better materials with more rigid specifica-[illegible] and better treatment with more thorough co-opera-[illegible] handling the work and with a more intelligent appre-[illegible] the designer is trying to accomplish.

CHAPTER LXVIII

SPECIFICATIONS IN GENERAL

THIS chapter will deal with the characteristics of in general and with the theory of specification writing LXXVIII will be found complete specifications for Chapter LXXIX complete specifications for The author has dealt with this subject previously at entitled "Engineering Specifications and Contracts", of this chapter are mainly taken from that work, to is referred for a more thorough and elaborate treatment.

Specifications prescribe the limits of the construction, the qualities of materials and workmanship which enter define the relations which shall exist between the parties of which they form a part, and the degree of responsibility to each. If complete plans have been prepared and all which affect the construction are known and fully the specifications should constitute a full and the construction, the materials and workmanship between the parties, the responsibility for accidents and bility of the completed structure, the terms of payment, matters which affect the work.

Specifications are drawn in the interest of the payer, contain ample safeguards to insure the construction of the cord with their letter and spirit; but they should be fair, or they will fail in their full purpose. Unless a contractor engineer and his principals to be fair beyond dispute in he must add materially to what would be a normal tender in order to insure himself against serious loss whenever tions govern. Even a close personal acquaintance and ence with the payer and his representatives are insufficient an unfair specification will not be enforced, because a pals or agents may, often does, take place during the contract; and a wise contractor will not run the risk of of the specifications without corresponding compensation every unfair advantage is paid for in the price of though it is of little or no value to the payer. specifications almost invariably operate to the whose interest they were drawn, by producing a spirit on the part of the contractor, leading him to

opportunity to demand extra compensation and extra time allowance for small considerations which are ordinarily overlooked where cordial relations exist. The payer may retain full control over the work and safeguard himself against bad materials and workmanship, against unreasonable delays, and against a contractor's dishonesty without the slightest injustice to the honest contractor, and if such action cause dishonest contractors to refrain from bidding, it is all the more advantageous.

The importance of the specifications, especially of their broad general clauses, is too rarely understood. If the engineer who draws them could exchange places for a time with the contractor, he would soon learn that over-stringent clauses operate to his detriment and, what is even more important, how it is possible to take advantage of his failure to specify definitely what he requires. As a rule, it is the broad general clauses that are most important, for they affect the entire work, while the clauses pertaining to details govern a small portion only. Ambiguous clauses are the most detrimental of all. They insure high tenders; for, in justice to himself, the contractor must assume that the interpretation most contrary to his interests will obtain. They provide the foundation for quarrels, law-suits, and vexatious and expensive delays.

Good specifications are the result of long and sound experience in construction and in the preparation of plans and specifications. If a part of the experience is obtained in the employ of contractors, the results are more likely to be satisfactory. The engineer's knowledge of what constitutes good construction and how to obtain it is the accumulation of years. The foundation for his knowledge—and the foundation only—may be laid during his course of study in a technical school. The weaknesses and effectiveness of the various clauses may be learned only by repeated use, and it is work well spent to review the specifications and contract after the completion of the work they governed, and note the desirable improvements and the fitness of individual clauses for future use. Thus the results of the experience on one contract may be made available for the next, but indiscriminate copying from the specifications of others, or even from one's own, is certain to produce bad results. Some years ago one of the engineering journals called attention to an absurd typographical error in a set of specifications which had been in print for several years, and pointed out the same error in the specifications of several prominent engineers, showing conclusively that some careless copying had been done.

It is impossible for our technical schools to teach men to prepare perfect specifications, but they can provide a good foundation by imparting a sound knowledge of the fundamental principles and such a thorough training in the use of the English language that the student will be able to express clearly what is in his own mind. Professional work, a further study of the law of contracts, and careful attention to the specifications prepared by competent engineers must supply the additional necessary training.

[illegible] the individual or [illegible] contractor who performs it [illegible] usually superintends its execution. [illegible] protecting the enterprise, and it devolves [illegible] those who retain him receive an [illegible]. While it is true that he is employed by [illegible] the contract, he should not be partisan, but [illegible] to both is secured. The engineer should [illegible] the contractor, but should work in harmony with [illegible] he can to further the rapid and harmonious [illegible] being careful, of course, to see that nothing is [illegible] may result in an inferior construction. As the [illegible] usually final (unless it can be shown that actual fraud [illegible] him to be careful that no injustice is done to anyone [illegible]

In order that the contractor may understand [illegible] to be performed and the details of its construction, [illegible] and plans, more or less complete, defining the [illegible] material, etc., to be used, are prepared by the [illegible] of the company having the work done and for the [illegible] tractor. These written documents are the [illegible] with the contract, of which they form a part, they [illegible] relations that shall subsist between the company [illegible] the contractor.

To build a structure, no matter how simple, [illegible] if it is to be constructed intelligently and efficiently. [illegible] importance of the structure increase, the plan grows [illegible] plex, and hence the greater necessity for putting it [illegible] definite form which shall convey the exact idea [illegible] the engineer. To secure the proper execution of a [illegible] tude, specifications are absolutely necessary, and they [illegible] with great care and exactness. For convenience of [illegible] clearness, they are usually divided into clauses, which [illegible] general and specific. General clauses refer to the [illegible] shall exist between the parties to the contract. In [illegible] general description of the work as a whole without any [illegible] ence to details. Times and methods of making [illegible] specifications, inspection, and other analogous [illegible] subject matter. They should be comprehensive in their [illegible] not contradict one another. It is well to avoid a [illegible] any particular thing. Contradictory clauses are sure [illegible] block that will create friction and delay. At first [illegible] that such clauses are easily eliminated, but care is [illegible] plish this. For instance, a certain result may be [illegible] ture of a bridge that will not fit in with the kind of [illegible]

Specific clauses have to do with the details of [illegible]

[illegible] incorporate in the work, [illegible]
[illegible] is requisite to set forth the exact [illegible]
[illegible] may be necessary to indicate clearly what is [illegible]
[illegible] drawings either should be prepared before the speci-
[illegible] or at least should be sufficiently matured in the
[illegible] to enable him to write his specifications in accord-
[illegible] must be remembered that the specifications and plans
[illegible] book for the contractor and the resident engineer;
[illegible] what must be done, but should not necessarily state just
[illegible] done. Specifications should look to the accomplish-
[illegible] rather than to the means of its attainment. Of course,
[illegible] to this, as when the engineer believes that for the
[illegible] must be performed in some particular way, in which
[illegible] to incorporate the method in the specifications. It
[illegible] that under these circumstances the contractor can-
[illegible] for the mistakes of the engineer. When an engi-
[illegible] a thing shall be done in a certain way, he must as-
[illegible] of the outcome, because the contractor is not free
[illegible] he thinks best suited to the case in hand. For this
[illegible] should leave the method, as far as can be done con-
[illegible] contractor, and instead should dwell upon the end to be
[illegible] contractor who is active and progressive may frequently
[illegible] methods of construction better than those conceived
[illegible] and it were a poor set of specifications which would pre-
[illegible] A specification can readily be very strict concerning
[illegible] and at the same time very liberal as to the methods
[illegible] its accomplishment.

[illegible] happens that the specifications are written without
[illegible] plans at all. In such cases it is usual to require bid-
[illegible] their tenders plans more or less detailed of what
[illegible] In this way the engineer may make a choice from
[illegible] and thus obtain what he considers the best of
[illegible] Specifications of this kind will have, of course, very
[illegible] all to do with the details involved, but will be con-
[illegible] with the final desired outcome. In other words,
[illegible] will consist very largely of general clauses, those of
[illegible] either entirely eliminated or reduced to a mini-
[illegible] letting contracts without any accompanying plans
[illegible] commended. A good engineer does not want other
[illegible] to use or what to do. If he is thorough and well
[illegible] he is not going to let his own ideas be super-
[illegible] who furnishes plans with his bid. In such
[illegible] only an inspector, who simply passes upon
[illegible] whether or not it fulfils requirements, when

perhaps much of the work is entirely
It is reasonable to suppose that an engineer
to designing structures of a particular kind (and
to cover the entire field) is more capable of
for a given case than a contractor who is engaged
nature, and who, perhaps, has given little or no
ing of the particular kind of structure upon which
It is undoubtedly a fact that the best results are
plans and specifications are prepared by a competent
the bidder is governed by their requirements.

Let us consider some of the salient features of
Primarily, they should give a clear and concise
first, when considered as a whole, and then in detail,
in this description. It will not answer for the
the contractor will do things as a matter of course,
a specification that will *insure* their being done. A
thoughtful and careful, will pay close attention to
in the specifications, and he should make his bid
the requirements enumerated in them, no more and
wise, he will not bid with the expectation of
conform to his convenience or his notions of what is
is supposed to have stated in his specifications just
no prudent contractor will tender with the
ideas will prevail. If, then, upon the engineer devolves
of determining the work to be done, it will readily be
him to cover the entire ground in his specifications,
special attention to the points he intends to require
alteration and should leave no possibility for doubt
contractor as to what will be expected concerning
careful to set forth clearly the units of measure to be
is to be considered a part of the finished work, as
is merely accessory. If extra work is to be performed,
which it is impossible to determine in advance, the
be exercised in defining clearly just what shall
and in fixing the compensation for it. Failure to do
source of trouble and annoyance that might be avoided

Specifications should be designed to secure the
with what is considered good practice. It is possible
ments of such a nature that to fulfil them would
lay of money not at all proportionate to the result.
specification make a bidder uneasy and cause him
sufficient amount in addition to his profit to
A bidder should make his tender expecting to
tions of the specifications and that his fellow
and a clause that involves an unduly strict

er to bid hoping that its fulfilment to the letter
in nine cases out of ten such a clause will be
absolute perfection is not to be expected, but the very
approved practice will afford should govern the re-
engineer must lose prestige if he specify things which
be done, and by inserting such requirements he works
concerned. In the matter of materials to be used,
by the locality and by what the market has to offer;
to get just what he would like; therefore, he must use
be obtained. These remarks do not imply that the
be satisfied with any makeshift that is offered. He can
he will not receive anything *better* than he demands,
if he succeed in getting everything as good as he speci-
large factor in determining what shall be considered good
not be content to put up with shoddy stuff when
obtained. As in all business relations, moderation with
govern.

tions should be written in simple, plain language with-
at rhetoric. All verbs should be complete, and no words
on the assumption that they are understood. Of course,
a contract or a specification in accordance with what
is its spirit, but an engineer should not rely upon this
omission. If the specifications are properly prepared,
no occasion for appealing to the courts to decide what is
intended. While such documents should be compre-
should not be verbose; and above all things they must not
short sentences and simple words are preferred. Punc-
while usually and erroneously considered of minor
engineer's practice, certainly play an important part
kind of literature. The meaning of a sentence can
or even entirely changed by the misplacing of a comma.
the same words or phrases over and over again in
if you find they best convey the idea you have in mind.
occasionally some lack of euphony, but that can very
with in writings of such a prosaic nature.

one contractor be employed upon a piece of work,
exercised to define clearly the duties of each. Just
and the other is to begin should be set forth so as
of doubt. When practicable in such cases, separ-
cifications for the different parts of the work should
should be taken that the same thing is not required
that one contractor is to leave his part of the
to involve no hardship or inconvenience for the
an illustration of cases of this kind, in bridge-
that one contractor will do the substructure

[illegible]

[illegible] what is to be [illegible]

The engineer must be careful about
anything that has even the appearance of
[illegible] on his guard to avoid this, for his pro
[illegible] is liable to suffer if he deviate in the least
[illegible] It is bad policy, generally speaking, to
of material or the product of a given firm wi
material will be accepted, if, upon testing, it be
When a given brand is well known and has
it is sometimes proper to specify that it shall be
other makes, but usually it is best to set a st
strate with the best product to be had, and then
meets the requirements. An exception to this
specifying paint for metalwork, because, unless the
stated, the contractor is liable to give endless tro
inferior brands, and the result is very likely to be
that is not really satisfactory. Unscrupulous parties
give the engineer a bonus in case he use their product,
is fortunate who has an extensive practice and is
all charges of peccability. Where one man's pro
another's used, there is a great temptation on the part
person to question the fairness of the proceedings
guilty of crookedness is badly handicapped, and
wishes to entrust the expenditure of his capital to
lutely above suspicion.

To insure that all the conditions have been
that the engineer must familiarize himself with every
in hand. If he does not understand it himself, it
not succeed in getting a clear idea of what he wants
another. Even when the scheme is perfected in the
is difficult sometimes to make it plain to the contractor

It will not do to jump at hasty conclusions,
finds that an idea, which at first seemed to be just
proves utterly untenable when considered in conn
ideas that must be incorporated in order to produce
struction. No idea for a specification has any value
fitted into the proposed structure, and is found to
other requirements.

It is usual and proper in specifications to insert
engineer the privilege of changing them or the pl
gresses, but it is desirable for all concerned that
changes be reduced to a minimum. A perfect set
render such a clause useless; but since we have
fection, we must have some means of recourse,

[illegible] as the one referred to is brought [illegible] that. [illegible] is one which should never be lost from [illegible] maintain his prestige, he must be precise. [illegible] "about this" or "about that," for the "about" [illegible] proportions which were never dreamed of when the [illegible] course, there are times when it is neither necessary [illegible] absolutely exact in requirements; but, generally speaking, [illegible]" has very little place in a set of specifications. [illegible] is placed there with the idea that it is to be operative [illegible] the construction of the work, and it is the duty of [illegible] all, to impose no impossible or unwise conditions, and [illegible] he has required is fulfilled to the letter.

[illegible] form a part of the contract, as was previously stated; [illegible] is signed, the contractor agrees to all the conditions [illegible] proper to assume that he has read the specifications [illegible] their requirements, and that he signs the contract and [illegible] with the full knowledge of what is before him. A specifi- [illegible] hide from the contractor the difficulties that are likely [illegible]. On the contrary, when such difficulties are known to [illegible] should be specially called to the contractor's notice, so [illegible] intelligently. His attention, however, should not [illegible] in such a way as to frighten him and to cause him to [illegible]ly high, but the facts as they exist and are known [illegible] should be stated. As in all relations in life, straightfor- [illegible] dealing is by far the best policy. No railroad com- [illegible] corporation is benefited by letting a contract for a sum [illegible] cost plus a reasonable percentage for profit, since the [illegible] the contractor's failure and the litigation that is likely [illegible] than counter-balance the supposed saving. No con- [illegible] money is going to make the same exertion to accom- [illegible]ly as one who realizes that he is earning a fair profit. [illegible] precaution that may be taken, it is almost impossible [illegible] entirely. A given proposition may appear to the en- [illegible] before work has commenced very different from what [illegible] after the construction has begun. When an engi- [illegible] he has made a mistake, he should not hesitate to [illegible] to set about, as best he may, to correct the error. [illegible] opportunity to check against errors, and should be [illegible] are discovered in time to prevent harm. To reduce [illegible] the engineer must be thoroughly conversant with [illegible] to arise in the execution of the work. He should [illegible] the appliances ordinarily employed, and should [illegible] their use is not prohibited. In writing his speci- [illegible] the plans, he should have a clear and complete

mental picture of just what he is striving to [illegible] bered that if the specifications are lived up to, the [illegible] the result, and that it is the plans and specifi[illegible] power of the engineer asserts itself.

Finally, when all is said and done, common sense [illegible] interpretation and execution of any set of specifications [illegible] but one object in view—the production of a structure [illegible] to everyone concerned.

All the bridge superstructure specifications that [illegible] be divided into two general groups: first, those which [illegible] ing, manufacture, and erection; and, second, those [illegible] facture and erection only. Specifications of the first [illegible] railroad companies, bridge manufacturing companies, [illegible] ing engineers; and those of the second type only by [illegible] gineers who do the entire designing of their structures [illegible] nothing in the line of detailing to the contractors, [illegible] ation of the shop drawings by elaborating the detail [illegible] by the engineer.

Whenever a consulting bridge engineer issues spe[illegible] instructions as to the designing and proportioning, it is [illegible] that he intends to make a practice of submitting [illegible] manufacturers for tenders, and letting the successful [illegible] designs subject to his approval. Designs evolved in [illegible] invariably inferior to those developed entirely by the [illegible] himself, and drafted in his own office directly under his [illegible] vided, of course, that the said specialist is thoroughly [illegible] competent.

The reader will notice that in this treatise the spe[illegible] signing are entirely separated from those for manufacture [illegible]

CHAPTER LXIX

CONTRACTS

of Engineering Contracts has been treated very fully in his book entitled "Engineering Specifications and Con- the subject-matter of this chapter has been largely drawn to which the reader is referred for a more complete dis- subject.

line between specifications and contracts is most difficult any particular case two engineers will rarely agree as to pertain properly to the specifications and what to the con- the specifications form a part. Some engineers prefer to everything into the specifications and thus keep the size of proper as small as possible, while others make the latter by including in it many clauses that are ordinarily found Again, others make a practice of repeating in the clauses that have already been covered in the specifica- method is objectionable in that it is liable to result in con- The author's preference is to throw as much of the into the specifications and reduce the size of the con- a minimum, avoiding repetition of statement in the two but of necessity treating certain subjects in both parts, points of view. There is no doubt about the proper of the topics or headings, but in certain cases there are for locating them in either division. All clauses that of construction, qualities of materials, character and work, rules limiting the functions and powers of the defining the authority of the engineer, directions to bid- tation of men and materials unquestionably belong to but such clauses as those relative to adherence to alteration of plans, damages, extras, payment, responsibil- spirit of the specifications, strictness of inspection, scope of the contract, and time of completion might, inserted in either division. The author's custom, all of these clauses and others of like character and

drafting contracts properly cannot well be over- drawn agreement is almost certain to involve pecuniary loss to an innocent party; hence it

[illegible] to study [illegible] art of contract writing. [illegible]

Before one can draft a contract, he must [illegible] and well defined idea of all the conditions and [illegible] epitomize these systematically before beginning to [illegible] to keep constantly in view the possibility that each [illegible] may be unscrupulous and willing to take every [illegible] every weakness which the said contract may contain [illegible] to his own profit—honor and integrity to the [illegible] Failure to bear this in mind will often result in [illegible] cause rank injustice to one of the parties to the [illegible] cult for an engineer to recognize this weakness of [illegible] keep it constantly before him when writing contracts, [illegible] ing and the work of engineers tend to develop in [illegible] degree the principles of absolute honesty; consequently [illegible] for them to be forced to make a practice of doubting [illegible] their business associates. To mistrust the motives [illegible] is disagreeable but essential, if the writer of specifications [illegible] is to protect himself or his clients from loss and fraud. [illegible]

The essential elements of any contract, according to [illegible] Wait, the noted authority on "Engineering and Ar[illegible] dence" are as follows:

First. Two parties with capacity to contract. [illegible]

Second. A lawful consideration: a something in [illegible] equivalent, a *quid pro quo*.

Third. A lawful subject-matter, whether it be a [illegible] a material object.

Fourth. Mutuality: a mutual assent, a mutual [illegible] meeting of the minds of the parties.

Without these four elements no contract is binding [illegible]

The essentials of a well-drawn contract that comes within [illegible] of the engineer, however, are as follows:

First. A proper and customary form.

Second. A full and correct description of all [illegible] agreement.

Third. A thorough and complete preamble.

Fourth. A statement of when and under what con[illegible] is to become operative.

Fifth. The limit, if any, for duration of contract. [illegible]

Sixth. An exhaustive statement of what each [illegible] binds himself, his executors, administrators, succ[illegible] or to refrain from doing.

Seventh. A clearly defined enunciation of the [illegible] each party is to receive—this is the essential [illegible] instrument.

[illegible] and a full statement of everything [illegible] eventuality.

[illegible] for failure to comply with the various terms of [illegible]

[illegible] for possible cancellation of contract.

[illegible] Provision for settlement of all business relations covered by [illegible] therefrom in case of cancellation, taking into [illegible] important eventualities.

[illegible] of the place where the agreement is drawn or [illegible] it is to be put in force, so as to show the state under [illegible] validity of the contract is to be determined, should [illegible] enforce it.

[illegible] Methods of payments, if any are to be made.

[illegible] Provision for extra compensation and the limitations [illegible]

[illegible] Provision for possible changes in contract.

[illegible] Provision for transfer of the contract or for sub-letting.

[illegible] Provision for settlement of disputes.

[illegible] Provision for satisfactory and sufficient bond, if any be [illegible]

[illegible] Provision for defense of lawsuits, if such provision be [illegible]

[illegible] Definition of names used in contract, such as "Engineer," [illegible] "Contractor," or "Trustee."

[illegible] Dating of contract.

[illegible] Proper signatures with the necessary seals, if the [illegible]

[illegible] Witnesses to the signatures or execution before a notary [illegible]

[illegible] be taken up and discussed in the order of their enumeration of these essentials to a properly drawn contract.

[illegible] of opening clause for contracts are both numerous [illegible] it is difficult to say which is the best. Each writer nat[illegible] favorite style and will adhere to it whenever pos[illegible] for many years has been as follows: (In order to [illegible] the usual blank spaces will be filled out with some [illegible] a date.)

> [illegible] AGREEMENT, made and signed this eleventh day of [illegible] between the Kansas City Bridge and Terminal Railway Com[illegible] State of Missouri, the party of the first part, and some[illegible] and in the specifications the "Company," and the [illegible], a corporation of the State of Kansas, the party of [illegible] termed in this agreement and in the specifications the [illegible]

Wait recommends the two following

This Agreement, made and entered into this eleventh
of 1905, by and between, etc., etc.

Articles of Agreement, made and entered into
and Terminal Railway Company, a corporation, etc., and The
Company, a corporation, etc., on this eleventh day of

After the introductory clause comes the
after it the author inserts in capital letters: "NOW
WITNESSETH," and follows with consecutively
embody all the terms and conditions of the contract
provision for the signatures and seals of the contracting
nesses to these signatures.

Second. In describing the various parties to an
be taken to make the description full and convincing
shall be no possible mistake concerning the identity of
is effected in the case of an individual by stating his
of residence, in the case of a firm by naming it fully,
of business, and describing the kind of partnership,
pany by giving its legal title and the name of the state
it was incorporated. In case of a partnership it is
specify whether it is general or special in respect to
in the contract.

While most contracts are drawn between but two
times occurs that an agreement will involve three
a contract is much more complicated and difficult to
tween two parties only.

Each party should be designated in the instrument
number, as the party of the first part or the party of
and in addition it is well to give each another designation
tractor," "Company," "Owner," "Engineer," "Promoter
"City," "Incorporator," or "Trustee," in order to avoid
many words throughout the document, as would be
always referred to as the party of the first or second
make assurance doubly sure it is well in some cases to
"Contractor," "Company," "Engineer," "Promoter,"
well as at the beginning of the document. In any
tory clauses should be placed at the beginning or the
fications, because the latter are often used without
attached.

There is no strict rule as to the order in which the
be placed, but it is customary to make the one
party of the first part. In case of employer and
should come first. In other cases it is a good rule

portant party first and the others as nearly as may be in the order of the importance of their relation to the enterprise or object-matter of the agreement.

There is a consideration of primary importance in contract writing that is sometimes overlooked, viz., whether the parties to the agreement are legally entitled to enter into contract. For instance, in the case of a company, the president or general manager, or perhaps either, can sometimes legally contract in the company's name, but sometimes he cannot, in which case, if haste be essential, it would be proper to have him enter into and sign the contract and afterward have it formally approved at a meeting of the board of directors. A properly certified copy of the board's approval should subsequently be attached to the contract. Access to its charter and by-laws is generally necessary to determine who has authority to enter into and sign contracts for a company.

In contracting no corporation can exceed the limit of its powers as given by its charter. If it attempts to do so, its act will be *ultra vires* and without effect; consequently it behooves one in writing a contract with a corporation first to study well its charter, articles of incorporation, and by-laws.

Contracting with unincorporated organizations as parties, such as associations, clubs, societies, or congregations, is a precarious business; nevertheless it often has to be done. In order to ensure the payment of money obligations by such parties a sufficient sum should be deposited in advance in the hands of a reputable trustee with instructions to pay it to the proper party or parties as soon as the obligations covered in the contract have been met. Otherwise, the other contracting party is liable to lose his entire consideration, because it is very difficult to hold legally an organization that has no legal existence, even if all the members thereof be individually liable.

Again, any person under twenty-one years of age, termed in law an infant, who enters into a contract, has the privilege of repudiating it after arriving at the age of maturity, in case that it does not redound to his advantage; consequently it behooves the writer of a contract to make sure in all doubtful cases that the contracting parties are of age. In engineering contracts, however, this question is seldom likely to arise because very young men are not often concerned in a prominent way with important enterprises.

Similarly, imbeciles, inebriates, and lunatics are incompetent, and contracts made by them are legally voidable at their option. While it is highly improbable that either an imbecile or a lunatic would ever be made a party to an engineering contract, it is not impossible that a man chronically addicted to the over-use of liquor might be so concerned. Such a man might plead that he was under the influence of drink when he signed the document, and thus possibly effect his release from its obligations, consequently the writer of an engineering contract should assure

[illegible]

A married woman in some States cannot [illegible]
[illegible] name. While it is uncommon for [illegible]
[illegible] involving engineering, it is by no means [illegible]
case has occurred in the author's practice. [illegible]

In case of war a contract entered into between [illegible]
[illegible] or citizens of the conflicting countries is [illegible]
[illegible] subsequent to the signing of the contract, [illegible]
be enforced by law until after the war has ceased. [illegible]
interested in projects in foreign countries, this is a [illegible]
be borne in mind when preparing the contracts for [illegible]

When a contract is entered into by an agent, [illegible]
make this relationship both clear and legal in the [illegible]
the name of the owner or corporation and following [illegible]
"acting by and through Mr. X., Agent, Attorney, [illegible]
or Treasurer (as the case may be), by virtue of the [illegible]
him through power of attorney of the (here name the [illegible]
pany) dated the ——— day of ——— 19—, a copy of [illegible]
annexed," or in some similar and equally explicit [illegible]
the name of the real principal is made certain, the [illegible]
is preserved, and the possible liability of the agent [illegible]
averted. It must be remembered that no claims or [illegible]
principal are created by a contract entered into by [illegible]
without proper authority, unless the contract be [illegible]
directly or indirectly by the principal.

Much engineering work is being done and is to be [illegible]
by contract with the United States Government. In [illegible]
tracts it is important to note that although the Govern[illegible]
suit on its contracts for their enforcement, it cannot [illegible]
consent, be sued for non-compliance therewith. In[illegible]
known of repudiation of contracts by governments. [illegible]
lic officers cannot be held personally liable for contra[illegible]
in their official capacity.

The names of the parties in the body of a contract [illegible]
exactly with the signatures and seals at the end, for [illegible]
prove fatal to the validity of the document.

Third. The preamble is a most important portion [illegible]
It should explain fully all the whys and wherefores of [illegible]
its *raison d'être.* A thorough explanation of the agree[illegible]
often render clear the intent of a clause in the body [illegible]
that is otherwise ambiguous.

Fourth. Every contract should contain a state[illegible]
what conditions it is to become operative. The [illegible]
ticular day of month and year or immediately after [illegible]

[illegible] such, for instance, as the [illegible] of a certain amount of money [illegible] tion of a certain piece of work, or the [illegible] point. Whatever the "condition prec[illegible] be made clear in the document beyond the possibility [illegible]

[illegible] in contracts nothing is said concerning the duration [illegible] of how it is to be drawn to a close. In some cases [illegible] able thus to limit the life of the contract; but [illegible] practicable but also advisable, and sometimes it is [illegible] where a bond for proper completion of work is [illegible]

[illegible] of what each party to the contract binds him[illegible] administrators, successors, or assigns, as the case may [illegible] from doing should be thorough and complete in [illegible] importance of this is self-evident, nevertheless it is [illegible] always given proper attention in contract writing.

[illegible] between corporations or between a corporation and [illegible] promises to perform should be made binding upon the [illegible] of each corporation, although it is probable that [illegible] this, even if the stipulation be omitted.

[illegible] an individual is a party to the agreement it is best [illegible] himself but also his executors or assigns, unless, perchance, [illegible] such a nature as to be non-transferable, as for in[illegible] of personal duties or services of an expert nature [illegible] skill. Thus an engineer's services are not transfer[illegible] special provision be made and agreed to by both parties [illegible] death or inability for good and sufficient reason to [illegible] contract is to be assumed by some other engineer either [illegible] determined afterward in some specific way. But the [illegible] of a firm of engineers will not cancel an agreement; [illegible] the original members of the firm remains in charge [illegible] hold. In other words, it would require the death or [illegible] original members of the firm to abrogate the con[illegible] provision to the contrary exist in the written agree[illegible]

[illegible] contracts are generally assignable, unless they contain [illegible] contrary.

[illegible] consideration which each party to an agreement is to [illegible] should be clearly and fully stated in the document, [illegible] contracts are liable to be held valueless and void in [illegible] consideration must be real, substantial, and ade[illegible] make a practice in many cases of specifying a con[illegible] and they even try to pass that dollar around [illegible] to the agreement by having each party make

nominally that payment to each of the [illegible] each receives a valuable (?) consideration. [illegible] a practice is mere humbug and unworthy of [illegible] tending to scientific attainments in his profession [illegible] that profession be law or engineering. Its adoption [illegible] dence of weakness in the document and a confession [illegible] he has failed to make evident the true consideration [illegible] is to receive and the real reason for each party's [illegible] agreement.

There may be some excuse for passing the dollar [illegible] deeding property to his child, where the true [illegible] affection; but a dollar does not constitute a real consideration [illegible] be insufficient usually to pay the cost of typewriting [illegible] its employment is a fiction and a farce.

Eighth. No portion of the work of contract writing [illegible] experience and ability than the forecasting of all [illegible] that would materially affect the agreement and the [illegible] what is to be done in the case of each eventuality. [illegible] more or less faulty in this particular, for it would [illegible] to forecast all future happenings; nevertheless, in [illegible] tant contract one should endeavor to foresee and provide [illegible] ties and probabilities. The lawyer or engineer who [illegible] giving this important matter full consideration in every [illegible] he writes will soon find himself in demand by capitalists [illegible] making their investments and in consummating their [illegible]

Ninth. The matter of penalties is one that has to [illegible] gloves, for the law is very jealous of its rights and prerogatives [illegible] that it alone is authorized to specify and enforce a penalty [illegible] terprets as a punishment for failure to perform or comply [illegible] of an agreement. On this account it is better not to use [illegible] alty" in any contract, but to employ instead that of [illegible] ages." The author has a clause in construction specifications [illegible] as follows:

"For each day of delay beyond the date set in the [illegible] pleting the entire work herein outlined, all in accordance [illegible] specifications, and directions of the Engineer, the Com[illegible] hold permanently from the Contractor's total compensation [illegible] ——— dollars; and the amount thus withheld shall not [illegible] a penalty, but as liquidated damages, fixed and agreed [illegible] the contracting parties as a proper compensation [illegible] the loss caused by such delay." Liquidated damages [illegible] forced, owing mainly to the characteristic good nature [illegible] they object to taking advantage of a contractor [illegible] fully but has been unfortunate. Again, the fact [illegible] jurors is generally with the working man and [illegible]

[illegible] involving the retention of money to compensate for [illegible] settled out of court.

[illegible] In most contracts for construction and in some [illegible] there is no need to provide for a possible abrogation [illegible] because the completion of the work involved is a nat- [illegible] but in some other types, such, for instance, as partner- [illegible] that continue indefinitely, full detailed provision should be [illegible] annulment at any time. Great care should be exercised to [illegible] fully how all current business matters are to be closed and what [illegible] is to be paid to the other party or parties by the party who [illegible] the said cancellation. To do this in a satisfactory manner will [illegible] business knowledge and ability of the highest order.

[illegible] It is quite important in many contracts to state where the [illegible] was executed and where it is to be put in force, notwithstand- [illegible] that the residence of each party in case of individuals or the [illegible] organization in case of corporations has been described in the [illegible] clause of the document. The laws governing a contract [illegible] determined by the place where the contract was made or by [illegible] which it is performed. Wait treats this question very thoroughly [illegible] to 51 of his "Engineering and Architectural Jurisprudence."

[illegible] Methods of making payments under construction con- [illegible] generally covered in the specifications, where they properly [illegible] all other types of contract in which payments of money are [illegible] provision should be arranged for the exact manner in which [illegible] both partial and final, are to be made. This remark ap- [illegible] special force to contracts involving engineering fees; for in [illegible] payments on account are not arranged for, there is a chance that [illegible] will receive no compensation at all until after the comple- [illegible] work, and this might be delayed for an indefinite period. [illegible] usual practice is to ask one-half of his fee upon the com- [illegible] plans and specifications and the other half in monthly pay- [illegible] proportionate to the amount of contract work done on the con- [illegible] that when the latter is finished he shall have been paid [illegible]

[illegible] construction contracts the subject of extra payments [illegible] the specifications, although in many cases it is covered [illegible] proper. The author's standard clause for this item reads [illegible]

[illegible] be allowed, unless they be ordered in writing by the [illegible] so allowed the Contractor will be paid the actual [illegible] materials and applied labor, plus twenty (20) per cent for [illegible] vouchers will be required from the Contractor for [illegible] materials. No allowance will be made for superin- [illegible] any other indirect expense."

[illegible] precaution to provide for making changes in

[illegible]
[illegible] change or alteration shall be made [illegible]
[illegible] agreement without the consent of [illegible]
[illegible] no claim shall be made or considered for [illegible]
[illegible] shall be authorized and directed in writing [illegible]

Sixteenth. In construction contracts there [illegible]
[illegible] assigning the contract and sub-letting the [illegible]
standard clause for this reads thus: "The party of the [illegible]
agrees that it will not assign or sub-let the work [illegible]
or any portion of it, without the written consent of the [illegible]
part; but will keep the same within its control." [illegible]

Seventeenth. In respect to provision for settlement [illegible]
views are somewhat at variance. Some think that [illegible]
be the sole arbiter, but such an arrangement is not [illegible]
does, altogether too much of autocratic rule. Arbitration [illegible]
best method of settlement of all disputes on important [illegible]
author's clause for this item is as follows: "The decision [illegible]
shall control as to the interpretation of drawings and [illegible]
ing the execution of the work under them; but if either [illegible]
sider itself aggrieved by any decision it may require [illegible]
finally and conclusively settled by the decision of three [illegible]
first to be appointed by the party of the first part, the [illegible]
of the second part, and the third by the two arbitrators [illegible]
case that the two first chosen fail to agree upon a third, [illegible]
be appointed by......................By the decision [illegible]
arbitrators or that of a majority of them, both parties [illegible]
shall be finally bound." The person chosen to appoint the [illegible]
should be some prominent official, such as the judge of a [illegible]
the mayor of a certain city, or the governor of a certain [illegible]
dom that an arbitration clause in a contract is utilized, [illegible]
as a rule are reasonable.

Notwithstanding the fact that the contract reads that [illegible]
cision of these three arbitrators, or by that of a majority [illegible]
parties to this agreement shall be finally bound," the [illegible]
that the losing party has still a right to appeal to the [illegible]
this clause of the contract is not absolutely binding. [illegible]
matters if immediately after an arbitration is agreed [illegible]
concerned were to give to the other a bond [illegible]
abide by the decision of the arbitrators.

Eighteenth. The bond question is a prominent [illegible]
struction contract, and occasionally is important in [illegible]
tract. The author has finally come to the conclusion [illegible]
Company bond is the only kind that he shall either [illegible]
future, for no other kind is so satisfactory to the [illegible]

with so little difficulty by the Contractor. All personal bonds are obtained by favor, and they are generally very unsatisfactory; for the solvency of the sureties is difficult to prove, and to enforce payment is still more difficult. There is considerable humbug in connection with sureties to agreements, for a slight change in contract, plans, or specifications is often sufficient to render the bond null and void. If anyone doubt this statement, let him read what Wait says on pages 13 to 17 of his "Engineering and Architectural Jurisprudence." In the author's opinion, the only way to protect the Company is to insist upon having a bond that will permit of all necessary changes in plans and specifications without releasing the surety, and even such a bond might be voided by the law's declaring it illegal because it departs from current practice.

Nineteenth. If, according to a contract, the Contractor is to indemnify the Company against all liability or damages on account of accidents, it is only fair that the former should be given the privilege of assuming the sole defense of all lawsuits arising from such claims.

Twentieth. The manner of defining by special clauses names used in the contract, such as "Engineer," "Company," etc., will be seen in the appended example of a contract.

Twenty-first. A contract can be dated either in the opening or in the final clause, or in both. In the latter case it is better not to repeat the date, but to insert the sentence "Dated the day, month, and year first herein written."

Twenty-second. It is important that the signatures coincide exactly with the names of the parties as given in the opening clause of the agreement, and that proper seals are attached when they are needed. If a party to a contract be a corporation its corporate seal should be used, but in the case of an individual almost any kind of a seal will suffice—either a wafer or the word "seal," with a scroll drawn around it with pen and ink, being commonly used. In the latter case it is better to write in smaller letters the initials of the signer over the word "seal." There is an important and fundamental difference between contracts with and without seals. The former do not need to have a consideration mentioned in them in order to make them valid, while the latter do require such mention. In former times there was far greater difference in the importance of sealed and parole (or unsealed) contracts than there is today; for then a sealed contract could not be modified without taking many formal legal steps, while today it can be changed quite readily by a short supplementary contract, provided there be a proper consideration mentioned therein for the making of the change.

Twenty-third. Where the party to a contract is a corporation, the proper witness to the Company's signature is the Secretary of the Company, who should use its corporate seal for attesting the document; but in case the party is an individual, any witness will suffice. The best possible witness to signatures is a properly authorized notary public; be-

state if any doubt be expressed
signatures, all that is necessary is to
is a matter of public record, while for all
to search for them and either produce them
impracticable to do so on account of death or
ty; and in this case it is generally required that
reliable parties who will swear that the witnesses'

The following is the form of contract that the
struction specifications:

CONTRACT

Memorandum of Agreement, Made and signed this..

of................19...., at.........................by and between

....

the party of the first part, and sometimes termed in this

tions the "Company," and..........................

....

....

of the second part, and sometimes termed in this agreement

the "Contractor."

Whereas,..

....

....

....

....

Now this agreement witnesseth:

First.—The party of the second part, for and in consideration

to be made to it as hereinafter specified, will..........

....

....

....

....

all in accordance with the plans and specifications

hereof, and will fully finish and complete the same by...

....

....

[illegible] Engineer, the party of the second part be delayed or pre- [illegible] that are absolutely beyond its control.

[illegible] of the second part shall start the work of construction as soon [illegible] contract as it is practicable to begin, and shall push the same [illegible] as possible.

[illegible] important dimensions and characteristics of the structure are fully [illegible] the accompanying drawings and specifications, which form a part of this

[illegible]—In consideration of the performance by the party of the second part of its [illegible] and agreements, as hereinbefore set forth, the party of the first part hereby [illegible] and agrees to pay the party of the second part as follows:

……………………………………………………………………

……………………………………………………………………

……………………………………………………………………

……………………………………………………………………

……………………………………………………………………

……………………………………………………………………

[illegible] case that there be any other materials furnished by the Contractor that are not [illegible] in this list, they shall be paid for on the basis of actual cost to the Contractor [illegible] twenty (20) per cent for his profit, it being understood (as stated in the "Un- [illegible] Work" clause of the specifications) that no indirect expenses of any kind will [illegible] in computing the cost of such materials.

[illegible] understood that no payments, either partial or final, are to be made for any [illegible] which is to be used for falsework or plant and that payment is to be made [illegible] which are left permanently in the finished structure and form a part [illegible] order to accommodate the Contractor, however, the Engineer may, at his [illegible] allow temporary partial payments in advance of the permanent work as [illegible] for plant and falsework are employed, but the Contractor shall have no right [illegible] such compensation.

[illegible]—The schedule prices to be employed in making partial payments for all [illegible] progress are to be determined by the Engineer.

[illegible]—All material paid for by the party of the first part shall be deemed to have [illegible] to and to have become the property of the said first party, but the [illegible] the second part hereby agrees to store it and to become responsible therefor [illegible] continuance of this agreement. If any of it be damaged, destroyed, or lost [illegible] cause, including, among others, floods, washouts, and fires, the Contractor [illegible] replace the same at his own expense to the satisfaction of the Engineer.

[illegible]—In case the party of the first part, notwithstanding the failure of the [illegible] second part to complete its work within the time specified, shall permit [illegible] party to proceed, and continue, and complete the same, as if such time [illegible] such permission shall not be deemed a waiver in any respect by the first [illegible] or liability for damages arising from such non-completion of [illegible] the time specified, and covered by the "Liquidated Damages" clause [illegible]; but such liability shall continue in full force against the said second [illegible] permission had not been granted.

[illegible] or alteration shall be made in the terms or conditions of this [illegible] consent of both parties hereto in writing; and no claim shall [illegible] for any extra work, unless the same shall be authorized and [illegible] the Engineer.

[illegible] of any delay in completing the work embraced in this con [illegible] part shall be entitled to no extra compensation on account [illegible] assumed that in submitting its tender it took its chances [illegible] delay. If, however, in the opinion of the Engineer, the Con- [illegible] of the Company to such an extent as to cause him serious [illegible] cessation of the work, the Company shall allow the [illegible] for such delay as may appear to the Engincer [illegible]

[illegible] second part hereby agrees that it will not assign or sublet [illegible], or any portion of it, without the written consent [illegible] will keep the same within its control.

[illegible]

appointed by the party of the first part, the [illegible]
and the third by the two arbitrators thus chosen [illegible]

fail to agree upon a third, the latter shall be appointed [illegible]

[illegible]

By the decision of these three arbitrators, or by that of a [illegible]
to this agreement shall be finally bound.

TWELFTH.—As, according to the terms of the accompanying [illegible] form a part of this contract, the party of the second part [illegible] of the first part against all liability or damages on account of [illegible] the omission or negligence of itself, its agents, or its workmen [illegible] of this agreement, and against all claims for royalties on patents [illegible] that the party of the second part shall be promptly and duly [illegible] party of the first part of the bringing of any suit or suits, and [illegible] of assuming the sole defense thereof. It is also agreed that [illegible] part is to pay all judgments obtained by reason of accidents [illegible] or suits against the party of the first part, including all legal [illegible] and other like expenses.

THIRTEENTH.—The Contractor further agrees to give to [illegible] company bond, satisfactory to the party of the first part, in [illegible]

.................................for the faithful performance [illegible]

the specifications, and of all the terms and conditions thereof [illegible] prompt payment for all materials and labor used in the [illegible] of the structures, and to protect and save harmless the Company [illegible] and from all damages to persons or property caused by [illegible] negligence by the Contractor, his agents, servants, or employees [illegible] connection therewith, and from injury to or loss of materials [illegible] either partially or in full before the completion and acceptance [illegible] constructions. In case the contract covers only the manufacture [illegible] metal, no bond will be required.

FOURTEENTH.—The word "Engineer" as used in this contract [illegible]

sulting Engineers of the..

....

....or their duly [illegible]

IN WITNESS WHEREOF, the parties to this agreement have [illegible] and seals.

Dated the day and year first herein written.

Witnessed by

....

....

In concluding this chapter there are a few general [illegible] tance to which the reader's attention is called, [illegible] often ignored in the preparation of contracts.

No erasure with a knife, rubber, or other similar [illegible] be made in any legal document, but if a mistake [illegible] be lined out in the case of handwriting and crossed [illegible] tition of the letter x in the case of typewriting, [illegible]

must evidently have been made while the document was being transcribed and before it was signed, while in the case of an erasure no one can say what was originally written, or that the correction was not made after the signing of the document. As a matter of precaution, it is advisable to have each signer of a contract initial on the margin of the page on which it occurs each correction that the document contains. This will show conclusively that all the interested parties concurred in making the changes. However, if a draft of an agreement contain many such corrections, it is better to have it recopied before obtaining the signatures.

Theoretically every contract should be written on a single page, for otherwise what is there to prevent a dishonest person from removing all the pages except the last and replacing them with similar pages containing matter prepared in his own interests? Some people meet this objection by pasting together in one continuous piece all the sheets of the document and marking in red ink on the joined parts a waved line that passes alternately from one sheet to the other. Others take the precaution to have all the parties to the agreement initial each page of the bound sheets. The manifolding of typewritten documents is a fairly good means for preventing the making of fraudulent changes in such papers; but in case that all the copies but one are destroyed, this check would become inoperative.

Contracts executed on Sunday are illegal. They may be agreed upon and drafted on Sunday, but to be valid they must be dated and signed on some other day of the week.

It is always advisable to let a contract "get cold" before signing it, *i.e.*, it should be set aside for at least one night and read over carefully the next day by all the parties in order that each may make sure that the document expresses exactly in every particular what has been agreed upon verbally, and that there is no clause in it prejudicial to his interests. By giving the mind a rest one is often able to comprehend a document more clearly, and thus save himself or his clients future trouble or pecuniary loss.

After an engineer has prepared a contract and has added all the finishing touches to it, he should submit the draft before it is signed to a competent lawyer for his comment. This is better than letting the lawyer draw it in the first place; and although a competent engineer can draft an engineering contract better than any lawyer, nevertheless an independent check is necessary for any important document, and who so competent to check a legal paper as an attorney!

CHAPTER LXX

REPORTS

THE preparation of reports, like that of
important and responsible classes of work that an
to perform. It involves not only a wide
sound judgment based upon a practical
and no inexperienced engineer need expect to be
of reports of any great consequence.

The reports that bridge engineers are usually
may be included under four heads, viz.,

First. Reports on conditions of old structures,

Second. Reports on values of existing structures,
capacity.

Third. Reports on projected structures.

Fourth. Reports upon plans, upon errors
structures, and upon methods of construction,
progress.

Many such reports have to deal not only with
allied constructions; hence the necessity for a
posted on other lines of engineering than his specialty.
connection with many bridge projects there are
or highway approaches, station-houses, power-houses,
nals, train-sheds, steam or electric machinery, and
These adjuncts complicate greatly the reporting
and render necessary either a very broad experience
engineer or the calling in of outside expert assistance.
the more experienced an engineer is in his own
is he to call upon engineers in other lines to aid him
of his practice in which he does not consider himself
sequently the making of an important engineering
joint effort of two or more engineers who specialize

The question of what should and what should
gineer's report is contingent upon several important
the first place, it will depend upon who the person
dressed. If he be an engineer or a man fairly well
treated, the style of the report may be quite
should be written specially for the layman; and
gineering matters which it contains should be
any one of ordinary intelligence may understand

ond place, it will depend upon whether the report is to be published or not. If it is, a formal and strictly correct style, which is not essential in a document of a personal character, will be required. In the third place, it will depend upon who its principal readers are likely to be and how interested they are in the project, for if they are busy men in other lines of work, the report should be as short and concise as practicable; but otherwise it may be made quite full in detail. In any case, though, the text should stick closely to the matter in hand, and should be made no longer than is really necessary to accomplish the desired purpose in the most effective manner possible.

All reports should be written in some logical sequence so as to hold the interest of the reader and prevent its flagging until the last word has been perused. This sequence may be that of time, that of importance, or that of some special consideration peculiar to the subject under discussion.

It almost goes without saying that absolute integrity is a *sine qua non* in the preparation of any report. The writer should take great care to maintain constantly a fair, judicial attitude in order that his advice may not be colored by his desire rather than by his judgment, and to ensure that all favorable and unfavorable considerations may receive their proper weight. A too favorable report may lead clients into an unprofitable investment not only to their ultimate detriment but also to that of the engineer; while, on the other hand, a pessimistic report may prevent the profitable employment of capital.

A masterly style of composition and a fine command of language go far toward making a report successful; but these *desiderata* cannot be attained without a thorough training in the study of one's own tongue. Technical writings, in order to produce the best possible effect, should be characterized by vigor, conciseness, fluency, power, logic, seductiveness, and the capacity to retain interest. Without these attributes engineering reports are liable to fail more or less in their purpose. Concerning the usefulness to an engineer of a command of his own language, the reader is referred to a paper on "The Value of English to the Technical Man," by John Lyle Harrington, Esq., Consulting Engineer, which was delivered as an address to the students of several engineering schools early in 1906, and was published soon after in pamphlet form and copied widely by the technical press. It is to be found also in a book entitled "Addresses to Engineering Students," edited by Waddell and Harrington.

It is by no means easy to outline what reports on bridge matters should contain and how the various questions involved should be treated, because there is no great similarity between the cases which arise in an engineer's practice; but by dealing separately with each of the four previously mentioned types, there may be given a few general ideas that will prove of value.

In reports on the condition of existing structures, one should mention

[illegible]
[illegible] should [illegible]
[illegible] ability to carry existing loads
[illegible] in determining its actual capacity,
[illegible] discovered and state their gravity; should
is to be retained (either with or without
should describe fully what must be done to
so long as it remains in service. A speed-limit
advisable; and an estimate of cost of repairs
should usually be included in the report.
In reports on the value of existing structures
cities one should give a full description and a
under consideration, should state its carrying
otherwise to transport both the loads to which
which are liable to cross it in the future, should
life and the cost of future repairs, should indi
structure to carry modern live loads would cost,
statement of present and probable future annual
and operation, and should show the present earn
likely to be increased or diminished in the future.
the price asked for the structure, he should give his
ness and as to what the bridge is really worth.
vise his clients fully in every particular about the
sale of the structure, stating clearly and unequivo
cons so that they may be fully informed concerning
portance in connection with the pending negotiations.

In reports on projected structures one should
the character of the proposed construction, and
the design, building, and operation of the bridge; should
estimates of first cost, operation, maintenance, repairs,
revenue; should treat of the feasibility of the project
view, and should summarize by making a clear state
and unfavorable factors and by giving the resultant
have been properly weighed and digested.

In reporting upon designs prepared by other
in a rather delicate position; because, on the one
violate professional ethics by too severe criticism
practitioners, and, on the other hand, he must
terests by pointing out clearly and unmistakably
may discover, and he must not hesitate to express
cerning the feasibility of the design or the advis
that it illustrates. Each case of this kind as it
upon its own merits, for no general procedure can
The same difficulty exists in reporting upon alle
existing structures and upon methods of constr

[illegible] apply in these cases and [illegible] methods of preparing reports [illegible] from his practice in 1907, are a good illustration [illegible] copies, the only changes of importance [illegible] and places, which good reasons in this particular [illegible]

[illegible] the firm was consulted by Mr. Blank, the [illegible] company, about the replacing of an old and [illegible] the Minnehaha River. The old drawings of the [illegible] submitted by Mr. Blank as the basis of a prelim[illegible] for rebuilding or replacing the bridge, it being un[illegible] accurate report and estimate would follow later [illegible] and other investigations were made. The preliminary [illegible] accompanied by a drawing, reads thus:

[illegible] our promise, we have prepared a layout and estimate of cost [illegible] approaches for the crossing of your Minnesota Midland Railway [illegible] at Carlsbad, and beg to report as follows:

[illegible] by the accompanying blue print, we have made the centre line [illegible] the main river parallel to that of the old structure, but two [illegible] stream. Starting from the West side of the main river, the [illegible] piers of the new bridge are located respectively directly [illegible] the first seven piers of the existing structure, but the eighth, [illegible] new piers are about twenty-five (25) feet nearer to the East [illegible] corresponding piers of the present bridge. The object of [illegible] shown quite clearly on the drawings, is to permit the new [illegible] on falsework up and down stream without interfering with [illegible] swing-span or with navigation.

[illegible] that the river is encroaching on the East bank at the bridge site, [illegible] hundred (100) foot plate-girder span at the East end, and have [illegible] abutment resting on piles driven to bed-rock. The spans [illegible] counting from West to East are as follows: Seven, open-[illegible] fixed spans of about two hundred and two (202) feet each, [illegible] hundred and seventy-six (276) feet, one open-webbed, riv-[illegible] of about three hundred and sixty-two (362) feet, and one [illegible] span of about one hundred and one (101) feet. All piers [illegible] concrete, the piers resting on pneumatic caissons of timber [illegible], and the abutments being supported on piles driven to [illegible]

[illegible] Red Eagle Chute we have adopted the centre line of the [illegible] centre line of bridge, and have counted upon retaining the [illegible] examination of them proves that they are either in satis-[illegible] put into such, building a new concrete pier on piles mid-[illegible] piers, removing the existing spans, and putting in half-[illegible] instead. We have not figured on doing anything to the [illegible] Chute bridge, for the reason that we have not yet exam-[illegible] be that we shall advise building a short span at each [illegible] abutment, but our estimate does not contain an allow-[illegible]

[illegible] we have joined the line of the new bridge to the

old line on the Island by a long, easy curve of [illegible] [illegible], and at the East end we have adopted a long [illegible] of the two curves of the existing line.

"In making the following estimate of cost we have [illegible] and labor, but have had to assume from the old [illegible] as an elevation of bed-rock which we think is [illegible] the uncertainty of the bed-rock data, this estimate must [illegible] proximate; but as soon as our Mr. Major completes the [illegible] start making next week, we shall prepare you a more [illegible] able estimate of cost. We do not, however, anticipate [illegible] from this one.

Superstructure of Main Bridge, including Operating [illegible]
ery and House ....
Superstructure of Red Eagle Chute Bridge.........
Substructure of Main Bridge..................................
Substructure of R. E. Chute Bridge.........................
Embankment, 4,000 lin. ft. at $10.00......................
Small bridge in East Approach...............................
Draw Rest...
Removing two old piers..
[illegible]
Engineering 5 per cent..
Grand total cost of [illegible]

"We have assumed that the removal of the old spans [illegible] salvage will at least offset the cost. If, though, as we [illegible] be wrought iron, its value will be greater than the cost of [illegible]

"Trusting that this report will meet with your approval, [illegible]

Very respectfully [illegible]
WADDELL & [illegible]

A month later the second report previously [illegible] Mr. Blank. It reads thus:

"On the 18th ult. we sent you a preliminary estimate of [illegible] over the Minnehaha River at Carlsbad, based on the old [illegible] tral Bridge Company and upon the assumption that the [illegible] was a fit foundation for pneumatic caissons. Again, since [illegible] the site with the idea in mind of rebuilding the bridge, we [illegible] lengths of both the main structure and the bridge over the [illegible] these accounts, as stated in our report, the estimates therein [illegible] to revision after borings and other investigations were made. [illegible]

"As you know, Mr. Major has for some time been making [illegible] 28th ult. Dr. Waddell visited the site and studied the [illegible] of Mr. Major's borings up to date show that near the East [illegible] pan" consists of a layer of blue clay or gumbo three (3) feet [illegible] it is harder and about fourteen (14) feet thick, and that at [illegible] there is no clay at all. Below the clay on the East side there [illegible] sand, then a layer of firm sand, followed by sand and gravel [illegible] had to abandon the idea of using the pneumatic process, [illegible] and have adopted instead foundations of long piles sunk [illegible] some twelve (12) feet up into timber shells filled with [illegible] being placed two (2) feet below low water level. In order [illegible] ber of piles, these shells or boxes have to be made [illegible]

matic caissons previously figured upon. Thus both the increase of volume and the piles in the foundations augment the cost of the piers.

"Again, we have had to figure on going seventy (70) feet below low water with the caisson of the pivot pier instead of only about twenty (20) feet, as we did in the preliminary estimate.

"The result of Dr. Waddell's visit to the site caused us to lengthen the main bridge about one hundred (100) feet and the Red Eagle Chute structure about four hundred (400) feet, provided that both bridges and the approaches are made permanent in character throughout by replacing all wooden trestle with earth embankment and thus closing all the little openings on the island and on both banks, which openings now permit the passage of water during the flood stages.

"All the preceding modifications have increased the cost over that in our preliminary estimate; but we were fortunately able to make one change that reduced the cost over sixty thousand dollars ($60,000.00), viz., by raising the grade of the Red Eagle Chute Bridge and adopting sixty-six (66) foot deck instead of one hundred and one (101) foot half-through plate-girder spans.

"The following is our revised estimate of cost of a single track bridge, counting from the abutment on the East shore to the abutment on the mainland of the West shore, and including the earth embankment over the island, as well as a small span in the East approach.

Superstructure of Main Bridge, including Operating Machinery and House	$342,000.00
Superstructure of Red Eagle Chute Bridge	58,500.00
Substructure of Main Bridge	171,000.00
Substructure of R. E. Chute Bridge	54,500.00
Embankment	31,000.00
Small bridge in East Approach	13,000.00
Draw Protection	10,000.00
Removing two old piers,	7,000.00
Summation =	$687,000.00
Engineering 5 per cent	35,000.00
Grand total cost of structure =	$722,000.00

"This shows an increase over our preliminary estimate amounting to $72,000.00, which is not excessive, considering the facts that we have had to adopt more expensive foundations and that we have increased the total length of bridge about five hundred (500) feet.

"During your interview with Dr. Waddell on the evening of the 29th ult. you requested us to make for you some estimates of cost of the proposed new bridge on the basis of building the piers for future double-tracking. In compliance with that request, we have made an exhaustive study of all the practicable methods of building at first a single-track superstructure and later substituting for it a double-track superstructure.

"We consider it exceedingly bad practice to load eccentrically any more than can be avoided bridge piers that rest on pile foundations; therefore we have figured on first placing the single-track spans symmetrically on their supports, then moving them laterally when the capacity of the bridge is doubled.

"The following is a list of what we deem to be all the practicable methods of building the structure first for a single line of railway and afterward enlarging it for a double line.

Method No. 1. Build the piers long enough now to carry two single-track superstructures spaced as closely as possible, with a single-track swing-span that has to be

removed entirely in the future and replaced by a double-track swing-span. This method would be necessitated by the inability to stop all river traffic long enough to put longitudinal falsework under the old span, take down the said draw, erect the new swing-span, and remove the falsework. In your case you generally can count upon just sufficient time to do all this, but in certain seasons the ice does not form enough to stop the steamboat traffic.

"*Method No.* 2. Build the piers long enough now to carry two single-track superstructures, with a double-track draw-span of the requisite extra width, but omit temporarily the two outer rows of stringers.

"This method is also suited to the conditions mentioned for the first case.

"*Method No.* 3. Build the piers long enough now to carry two single-track superstructures, and arrange to move the single-track draw-span to one side on the drum and to build a duplicate thereof beside it. This method could not be adopted unless the steamboat traffic were stopped.

"*Method No.* 4. Build the piers long enough now to carry two single-track superstructures, and construct the draw-span according to Waddell's patented method of transforming single-track spans into double-track spans. This method, which will be explained fully later, will not interfere at all with river navigation.

"*Method No.* 5. Build piers nearly but not quite as long as in the preceding cases and the entire superstructure according to Waddell's method just mentioned. The erection of this type of structure would not interfere with navigation.

"Waddell's patented method consists in spacing all the stringers equidistant, leaving out temporarily the two outer lines of stringers and arranging to swing them easily into place afterward, building the floor-beams for the double-track loading, designing the trusses for single-track loading, and arranging to place outside of them in the future duplicate trusses connected to the old ones very rigidly by diaphragms. The new trusses would be erected without falsework by a small overhead traveller and by needle-beams suspended beneath the floor-beams, and they would carry their correct share of the load when properly connected to the old ones.

"The following are our estimates of cost of the structure over the main channel only, exclusive of the engineering, by each of the five suggested methods of construction.

METHOD NO. 1

	Original Cost	*Final Cost*
Superstructure	$342,000.00	$759,000.00
Substructure	322,000.00	322,000.00
Total =	$664,000.00	$1,081,000.00

METHOD NO. 2

	Original Cost	*Final Cost*
Superstructure	$409,000.00	$657,000.00
Substructure	322,000.00	322,000.00
Total =	$731,000.00	$979,000.00

METHOD NO. 3

	Original Cost	*Final Cost*
Superstructure	$342,000.00	$702,000.00
Substructure	322,000.00	322,000.00
Total =	$664,000.00	$1,024,000.00

Method No. 4

	Original Cost	*Final Cost*
Superstructure	$361,000.00	$664,000.00
Substructure	322,000.00	322,000.00
Total =	$683,000.00	$986,000.00

Method No. 5

	Original Cost	*Final Cost*
Superstructure	$377,000.00	$605,000.00
Substructure	308,000.00	308,000.00
Total =	$685,000.00	$913,000.00

"If the structure be built originally for double track, the cost would be as follows:

Method No. 6

Superstructure	$566,000.00
Substructure	297,000.00
Total =	$863,000.00

"Let us compare these methods so as to determine which is the best.

"If we assume that the rate of interest is five (5) per cent compounded, the following table will give the true total cost of structure after it has been rebuilt for double track at the expiration of certain terms of years.

Method	Total Cost in Thousands of Dollars of Double-Track Structure After							
	5 Yrs.	10 Yrs.	15 Yrs.	20 Yrs.	25 Yrs.	30 Yrs.	35 Yrs.	40 Yrs.
No. 1	1,264	1,499	1,797	2,178	2,665	3,287	4,080	5,072
No. 2	1,181	1,439	1,768	2,187	2,723	3,407	4,281	5,372
No. 3	1,207	1,442	1,740	2,122	2,608	3,230	4,023	5,014
No. 4	1,174	1,416	1,722	2,125	2,616	3,255	4,071	5,091
No. 5	1,102	1,344	1,652	2,045	2,547	3,188	4,007	5,030
No. 6	1,101	1,406	1,794	2,290	2,922	3,729	4,761	5,050

"From this table it will be seen that at the end of five years it is a stand-off between Nos. 5 and 6; that for ten, fifteen, twenty, twenty-five, thirty, and thirty-five years No. 5 is the most economical method, and that after about thirty-eight years No. 3 is the most economic. Or, in other words, at the end of five (5) years the cost of the double-track bridge and that of Waddell's special structure are the same, from five (5) to about thirty-eight (38) years the special structure is the most economic of all, and after thirty-eight (38) years the method of duplicating the spans throughout is best. As there is practically no chance of there being any necessity for double-tracking during the first five years, and as the call for greater capacity will in all probability come before thirty-eight years, it is evident that Waddell's special structure is the best one to adopt.

"Assuming this to be the case, the following table gives our estimates of total cost for the various cases that you will probably consider.

"There is another possibility that we have not yet considered, viz., that when greater capacity is required, it might be more economical to build another single-track bridge either above or below the old one and as close to it as the War Department and the existing conditions will permit. The least allowable distance between bridges is, ac-

Items	Single-Track Structure	Double-Track Structure
[illegible] River Bridge..............	$513,000	[illegible]
[illegible] Eagle Chute Bridge........	113,000	202,000
Embankment.....................	31,000	40,000
Approach Span..................	13,000	22,000
Draw Protection................	10,000	17,000
Removing old piers.............	7,000	8,000
Summation......................	687,000	1,158,000
Engineering....................	35,000	53,000
Grand Total....................	722,000	1,211,000

cording to law one-third of a mile. There are two objection
extra cost of the single-track embankment between the junction
old lines, which we may assume to be about one hundred
second, the extra expense of operating two swing-spans,
would be about fifty thousand dollars ($50,000).

"Upon these assumptions we have figured the total cost of
capacity for traffic at different periods, and have recorded the
table.

Type of Structure	TOTAL COST IN THOUSANDS OF DOLLARS FOR				
	5 Yrs.	10 Yrs.	15 Yrs.	20 Yrs.	25 Yrs.
Double Track....	1,547	1,974	2,520	3,216	4,105
Waddell's Patented Structure...	1,529	1,865	2,293	2,841	3,538
Two Structures..	1,795	2,048	2,373	2,787	3,317

"From this table it is evident that under no condition
economical to build a double-track structure at present, unless
plainly in sight; and that for seventeen (17) years the special type
be most economical, after which two separate structures would
that there be a good and suitable location within a mile of the

"In case that you adopt the special type of construction
for you, there would be no charge for royalty on account of

"Although our Mr. Major has not yet finished making
so far obtained are sufficient to assure us that his complete
modify the above estimates of cost of foundations. And
not final, they will, we trust, enable you to reach a conclusion
ing the type of structure to build, an end which the condition
in our opinion, renders urgently desirable.

"You asked Dr. Waddell what are the probable amounts of
have to spend from month to month on your proposed new
work of construction be pushed as rapidly as practicable,
made computations from which we reach the following

"Assuming that on January first you give us an order
tion of plans and specifications and to call for bids as
pay for a single-track structure would be required in

[illegible]	[illegible]	Oct. 15	$170,000
[illegible]	24,000	Nov. 15	80,000
[illegible]	24,000	Dec. 15	30,000
[illegible]	30,000	Jan. 15	62,000
[illegible]	120,000	Mar. 31	7,000
[illegible]	146,000		
		Total =	$722,000

[illegible] estimates are made on the first of each month and that the corre[illegible] become due on the fifteenth of same. The April payment in[illegible] the entire engineering fee, which, according to custom, is due upon [illegible] the plans and specifications, the remainder being paid monthly in [illegible] monthly estimates for construction. The May, June, and July [illegible] substructure only. Those for August, September, and October in[illegible] all the superstructure metal at site, as well as substructure work [illegible] of erection of the spans. The January figure is high because [illegible] ten (10) per cent. The March estimate is for the removal of [illegible] which work cannot be done until after the new structure is in opera[illegible] the old spans are taken down. We have made no allowance for the [illegible] the old spans, as this would be more than offset by the value of the

[illegible] figures for a single track structure on double track piers, with [illegible] according to the patented method are as follows:

[illegible]	$44,000	Oct. 15	$204,000
[illegible]	42,000	Nov. 15	120,000
[illegible]	42,000	Dec. 15	34,000
[illegible]	54,000	Jan. 15	66,000
[illegible]	148,000	Mar. 31	9,000
[illegible]	180,000		
		Total =	$943,000

[illegible] figures for a single track bridge on double track piers, with the [illegible] built according to the patented method are as follows:

[illegible]	$46,000	Oct. 15	208,000
[illegible]	41,000	Nov. 15	118,000
[illegible]	41,000	Dec. 15	35,000
[illegible]	52,000	Jan. 15	68,000
[illegible]	150,000	Mar. 31	9,000
[illegible]	184,000		
		Total =	$952,000

[illegible] January first as the best time to start your construction, for [illegible] you would be able to complete the new bridge in twelve [illegible] start at an unfavorable time, it might require a little longer. [illegible] report will make clear to you everything in connection with [illegible]; but if you desire any further explanations or investi[illegible] to furnish them.

"Very respectfully yours,

"Waddell & Harrington."

CHAPTER L

ADMINISTRATION OF CO

The method of letting construction co
of cost plus a lump sum has been
some of the large cities, but it is never likely to
method of letting them in competition by
There is a good deal to be said on both sides of the
of the advocates of the “Percentage Method
Work” was so well stated by an anonymous w
of October 10, 1891, that the author has decided
referred to the following presentation of their case

“The owner is assured from the start that the work will be
chief temptation for slighting it has been removed. He is
material bills will be paid and that there will be no liens
ture. He is at liberty to make various changes in the work
out first obtaining the consent of the contractor, and he is
contractor at work on the job as soon as the principal features
out waiting for all detail plans to be completed.

“If there is any uncertainty about the nature of the
the extent of possible difficulties and delays, or the details of
tractor of experience will make a bid on the work without al
In this way the owner has to pay a large sum for the risks
and he might as well take some of those risks himself. Again
of work some bidder may carelessly omit or overlook some
up his estimate of cost, and thus get the work awarded to him
cost. It is better for the owner to pay what a job is actually
tractor is losing money, either from his own mistakes, including
his bid, or from difficulties that could hardly have been antic
nature for him to endeavor to get even in some way, and the
will suffer in consequence, despite great care and watchfulness
gineer. And it is difficult for the average engineer, when he sees
struggling with an unprofitable job, to harden his heart to such
all the nicety of construction that he would exact if he knew
money on the work.

“With the percentage method the owner is at liberty to
or as cheap as he pleases. He should have his own trusted
accounts, and he should be careful to select the right contract
honorable and capable men among contractors who would
terests of their employers, if given a contract on the percent

The author acknowledges that there are conditions
the method of letting work at cost plus a percent
sum, or even the method known as “ day labor,”

[illegible] the adoption of any one of the three [illegible] a last resort, applicable only when it is impossible [illegible] contractors to undertake the work on the usual [illegible] how honest or honorable a contractor may be [illegible] percentage" job, there is no ensuring that his employees [illegible] honorable. In fact, one can count confidently upon [illegible] consequently, when there is no one on the work [illegible] they will "soldier" to such an extent that the [illegible] eventually cost from fifty (50) to one hundred (100) per [illegible] ought. Human nature is human nature the world [illegible]tely, it is so constituted that, especially in the lower [illegible] will not labor to advantage without some mental spur [illegible]. When a workman feels that the more a piece of [illegible] greater will be the profit to his employer, he will not dread [illegible] discharged on the plea of laziness. The author is speaking of what he knows, for he has done some millions of dollars' [illegible] construction by administration; and, although his con[illegible]able and desirous of doing the work expeditiously and [illegible]theless it was practically impossible to make the [illegible] themselves as they would have done under the usual [illegible]contracting.

[illegible] important bridge construction economically by day labor [illegible] and a dream, as any railroad company which has tried [illegible] it is difficult to make the day-labor method pay even [illegible] ordinary bridge maintenance and repairs, and when [illegible] railway managers find that it is economical to con[illegible] builders, even if it should become necessary to do [illegible] percentage.

[illegible] ago the author had occasion to call for bids for the in[illegible] gasoline machinery to operate one of his old swing [illegible] for many years been turned by man-power. The ten[illegible] that he advised his client to do the work by day-[illegible] that the actual cost exceeded that of the highest [illegible] more work became necessary as the installation [illegible] would have occurred under any conditions; never[illegible]vinced through this experience of the futility of [illegible] by doing repair work to bridges by the day-labor [illegible]

[illegible]uction is done in a foreign country, it may be found [illegible] cost plus a percentage plan, but there should be [illegible] total profit; and, in fact, it would be better [illegible] degrees after certain previously determined total [illegible]ctures have been exceeded, making it disadvan[illegible] cost of construction be excessive.

Where foundations for bridges are
it may be advisable to let the work at cost plus
tive contractor of experience and well-established
ders are prone to tender exceedingly high when
known or uncertain conditions. If such work be let
the usual manner, and the contractor's estimate
been too high, the principal will have spent money
have been saved; while, on the other hand, if the
of cost prove to have been too low, the worries
that always ensue under such circumstances will,
make the principal wish that the contract had been
basis.

There is a method of letting contracts, evolved
Mr. C. F. Graff, President of the Graff Construction
Wash., which is far more satisfactory than that of
or that of cost plus a lump sum. It consists in
lump-sum expenditure to the client for the work,
contractor's profit will be either zero or a minus
as possible actual costs a number of other smaller
ing sums with a regularly augumenting sliding
to be added for contractor's profit, the latter
client and the contractor will share by another
between the greatest possible price and the actual
saving the larger the percentage thereof to go to the
standard methods of lump sum and unit prices,
no better, fairer, or more systematically adjusted
tracts than the preceding. The client is protected
cessive expenditure, and the contractor is given the
tive for keeping the cost down to the lowest
without saying that the client has the privilege of
accounts, or even of keeping a combined inspector
work from start to finish so as to see that all
materials are *bona fide* and that all the construction
oughly and economically. In view of the
scheme for letting contracts, and because the
may not be perfectly clear to every reader, the
illustrate it by an actual example taken from Mr.
let him explain in his own words the
method.

In May, 1912, Mr. Graff made a written
Council of Victoria, B. C., for the construction of
from a published copy of which the cost and profit
and the appended extracts have been taken:

> "The total expense to the city is thus guaranteed
> said guarantee to be covered by a satisfactory surety

costs intermediate to those shown shall be computed
proportion.

TABLE 71a

Cost and Profit Table for Percentage Bid on the Sooke Waterworks, Victoria, B. C.

Profit on Actual Cost		Total Cost to City in Dollars	City's Saving on Guaranteed Maximum	
Per Cent	Dollars		Dollars	Per Cent
0	0	1,450,000	0	0.0
1	14,300	1,444,300	5,700	0.4
2	28,200	1,438,200	11,800	0.8
3	41,700	1,431,700	18,300	1.3
4	54,800	1,424,800	25,200	1.8
5	67,500	1,417,500	32,500	2.3
6	79,800	1,409,800	40,200	2.8
7	91,700	1,401,700	48,300	3.3
8	103,200	1,393,200	56,800	3.9
9	114,300	1,384,300	65,700	4.5
10	125,000	1,375,000	75,000	5.2
11	135,300	1,365,300	84,700	5.8
12	145,200	1,355,200	94,800	6.5

mitted a proposition to the honorable water commissioner on a slid-
a percentage basis, which becomes automatically economical from
municipality as well as ourselves as managing contractors for the
the total cost of the work is reduced the percentage of profit is
the cost is increased the percentage of profit is reduced until, when
certain fixed maximum, these profits become zero, and we guarantee
cost to the city, including plant, profits, and all charges of every
any event, exceed this fixed maximum, and this guarantee is to
factory surety bond to protect the city. . . .

invite the attention of the council to the fact that unless some
outlined by us is resorted to, there is no assurance, so far as
as to what the ultimate cost of the work will be, whereas by
there is every incentive for the managing contractor to keep the
fact, absolutely essential that he do so, or his efforts will all be
We consider, and so will every sane business man, that for the
cost plus a percentage or fixed sum profit agreement without
cost would be ruinous; that even with such a guaran-
there is not the incentive to keep down the expense of the
the arrangement we propose. Our offer is a straight business
the whole responsibility of sound, economic, and scientific
solely upon the shoulders of the contracting manager equally
handling the work on a straight contract; and at the same
the necessity of completing the work on a cost basis, which
procedure now open to the city in view of existing condi-
only is the city absolutely sure of its position as to the
financially, but if, as the work progresses, it proves to be a
project is less than the general judgment now seems to indi-
will reap the benefit. Also, although as pointed out
automatically ensures economy, we would suggest that
method of checking the pay-roll and the expenditure

[illegible] and in the last analysis [illegible]
[illegible] absolutely uncontrolled and [illegible]
[illegible] to conduct his operations as [illegible]

Where bridge construction is done by [illegible]
volved for the engineers is far greater than [illegible]
to perform under the usual method of letting [illegible]
to their customary duties, they must approve [illegible]
plant and must O. K. in advance the purchase of [illegible]
wages and salaries paid, and every expense of every [illegible]
the construction. They must also look to the [illegible]
of all camps for the workmen, arrange for hospital [illegible]
medical attendance, see to the insurance of men and [illegible]
drinking water and make certain that it is boiled [illegible]
and have an eye on the commissariat, the stores, [illegible]
boarding of the men, so as to ensure that they are [illegible]
properly and at reasonable rates for the accom[illegible]
Again, the engineers must look carefully after the [illegible]
that all the money so charged goes to the employees, [illegible]
properly adjusted to the different classes of labor, [illegible]
time is correctly kept. Besides all these items of [illegible]
pense, the records of work done will be much more [illegible]
lesome to keep. In short, the work that the engineers [illegible]
do under the method of administration is excessive, [illegible]
bilities are increased greatly as compared with the [illegible]
usual method. On this account, as explained further [illegible]
they should receive increased compensation for [illegible]
construction is done by administration.

CHAPTER LXXII

ARBITRATION

[illegible] specifications (the author's included) contain a [illegible], it is not often that this method of settling [illegible]. Were it in more general use, there would be fewer cases [illegible] controversies between builders and contractors [illegible] easy and inexpensive manner of settling disputes, [illegible] to all who desire to do what is right and who [illegible] any undue advantage. When a board of arbitra- [illegible] engineers, one appointed by each of the contestants [illegible] two thus chosen, the decision reached is more likely [illegible] than that arrived at by either judge or jury; be- [illegible] are men trained by their life's work to consider just [illegible] raised in a controversy of this kind. Moreover, the [illegible] an eminently fair-minded man; hence there is every [illegible] arbitrators' verdict being the best that can be reached. [illegible] matters engineers almost invariably consider them [illegible] view of equity and justice and not from that of the [illegible] they are right; for the law is often hide-bound and [illegible] and judges too often cling closely to precedent and [illegible] the law, ignoring individual rights and the calls of jus- [illegible] not so well fitted to act as arbitrators on engineering [illegible] engineers.

[illegible] classes of arbitration with which a bridge engineer is [illegible]. The first and most common is the adjustment of [illegible] final settlement for a construction contract. The [illegible] determination of what proportion of the total cost of a [illegible] proposed or completed, each of two or more interested [illegible] pay. Ordinarily, the adjustment of a final settlement [illegible] after both sides have stated their claims and points [illegible] sense of equity does not indicate clearly the correct [illegible] compromise is resorted to, and a decision is soon reached. [illegible] of what each one of several joint owners or users [illegible] contribute to its cost is no simple affair. It involves [illegible] questions that sometimes appear almost incapable [illegible]

[illegible] the author's practice will illustrate this complexity. [illegible] had retained him to design and supervise the

building of a large and expensive bridge to carry wagon, pedestrian, and street railway traffic; and the street railway company was to contribute its proper share of the expense of construction. The city officials thought that the railway company ought to stand one-third of the cost, while the latter deemed that twenty (20) per cent ought to suffice; consequently the decision was left to the author to arbitrate, and his findings were to be adopted as final. The conditions of construction were in a way peculiar, for the cost of most of the substructure would not be increased by widening the superstructure to carry the double-track railway. The reason for this was that the bridge was in the nature of a highway trestle or elevated railroad across rather shallow tidewater, and the smallest pedestals that good practice would sanction had an excess of carrying capacity. The extra cost to the city, therefore, lay mainly in the wider superstructure. The company claimed that as the city intended to pave the railway space so as to permit driving over it, thus nearly doubling the width of wagonway, the city ought to share the expense for the increased width of structure. To this the city officials replied that they really did not need the extra space, but would utilize it if put on; and that the company ought to share in the expense of the substructure. There was also a further complication involved in the swing span. The author decided that the benefit the city would receive from the extra width of roadway would be offset by the free use by the company of the substructure, and that the company's fair share of the expense would be the difference in cost between the combined structure and the one without provision for the railway. Then he made a complete detailed estimate of cost for each case and found that the difference amounted almost exactly to twenty-five (25) per cent of the total cost of the combined structure, and reported accordingly. The decision appeared to satisfy both parties, and the controversy was adjusted in conformity therewith.

When a case of arbitration is left to a single engineer, he is put in a rather awkward predicament, while at the same time the appointment is of a highly complimentary nature. In such a case the arbitrator's fee should be equally paid by the two contestants, in order that he may not be hampered in any way by any false notions of loyalty to either client. The author once conducted a case of this kind, in which an expensive projected city bridge had its estimated cost increased by a railway company which desired to put its tracks beneath the city's structure. The city engineer and the chief engineer of the railway company had agreed upon the extra quantities of materials, but they disagreed about the unit values. As both parties were clients of the arbitrator, he was placed in a most uncomfortable position, nevertheless he managed to satisfy both of them. He handled the matter in this way:

The three engineers met at an informal luncheon with the intention of attending to the business immediately afterward. The arbitrator ex-

[illegible] that the job was one which he would have avoided [illegible] result in converting one or both of his good friends [illegible] they assured him that there was no danger of that, for [illegible] confidence in his impartiality. He then said that he would [illegible] the case by taking up each disputed item by itself, hear each [illegible] claim, try to get the two into an agreement, and, if unsuccess[illegible] decide the matter for them, and finally would compute the [illegible] amount for each item and sum up. He warned them that he [illegible] to tread on the toes of one or both parties—and tread hard. [illegible] engineer claimed a difference of $41,000, and the railway engi[illegible] should not exceed $30,000. Following out the programme, [illegible] was adjusted by mutual agreement with almost no coercion [illegible] of the arbitrator, and the excess cost was found to amount [illegible] or $1,000 less than the average of the two claims. Both [illegible] perfectly satisfied, and the arbitrator breathed a deep sigh of [illegible] the matter was concluded.

[illegible] disputes between the parties building bridges and their [illegible] most of the questions at issue are easily decided, if the speci[illegible] the work are thoroughly drawn; although occasionally some [illegible] where a sense of equity and justice must govern rather than [illegible] to the letter of the specifications. Every bridge en[illegible] be broad-minded enough to ignore his own specifications [illegible] would inflict an unforeseen and unjust burden upon a con[illegible] has done his work faithfully and well but has experienced [illegible] because of having encountered onerous conditions that [illegible] either by him or by the engineer. Under such cir[illegible] the company's engineer acts as an arbitrator between the [illegible] the contractor, but if either party deems itself aggrieved [illegible] it has the privilege of submitting the matter to an ar[illegible] persons, one chosen by each of the two contestants and [illegible] two arbitrators thus selected. The decision of the ma[illegible] arbitrators is supposed to be final, and is nearly al[illegible] nevertheless either contestant has the right to carry the [illegible] courts, and this is done on rare occasions. The result, [illegible] is that the court supports the arbitrators; and this [illegible] because in most cases the said arbitrators have acted [illegible] best judgment, and, as they are trained in the line of [illegible] findings are usually correct.

[illegible] advisable before inaugurating an arbitration to have [illegible] a bond guaranteeing that he will abide by the de[illegible]. Then if he is dissatisfied with the award, he [illegible] privilege of going to law; but to avail himself of [illegible] sacrifice the bond which he has put up. Such an [illegible] invariably result in making the arbitration

CHAPTER LXXIII

PROMOTION OF BRIDGE PROJECTS

Bridges which are not bought by railroad companies for their own [illegible] or by cities, counties, or townships for public benefit, generally owe [illegible] existence to the foresight, energy, and desire for gain of the class of [illegible] commonly known as promoters. This designation long ago carried [illegible] some idea of responsibility and high standing (both social and [illegible]) for the individual to whom it was applied; but of late years it [illegible] more a term of reproach than a complimentary appellation. [illegible] is due to the fact that America has gradually produced a class of [illegible] who make their living by their wits through foisting un[illegible] ventures upon a credulous public and trading on its natural [illegible] gain and the modern desire to get rich quickly. Notwith[illegible] this unsatisfactory state of affairs, the real, genuine promoter [illegible], but a public benefactor, in that he labors to inaugurate [illegible] which will be both a benefit to the community in general [illegible] source of profit to those who invest their savings therein. [illegible] promoter there would be but little progress, and the devel[illegible] country would be extremely slow.

[illegible] promoter is the individual who discovers the necessity for [illegible] or utility which will be appreciated by the public [illegible] that people will have to use it and pay adequately for [illegible] who has the ability to convince others of the soundness of [illegible] and who is gifted with the indefatigability and pluck that [illegible] ever giving up the fight, no matter how great his discour[illegible] man (and there are indisputably many of them in this [illegible] to the class which is making America great among na[illegible] furnishing the people with the wonderful conveniences [illegible] modern life, and which makes existence a source of pleas[illegible] burden grievous to be borne. All hail, then, to the true [illegible] of ideas, courage, indefatigability, sound business [illegible]; and may his days be long in the land!

[illegible] a high type of salesmanship; and one who is ex[illegible] therein would find it to his advantage to study thor[illegible] that calling.

[illegible] promulgated by promoters there are but few [illegible] projects; for bridges are a great boon to the [illegible] America everybody travels. Moreover, bridge [illegible] source of profit to those who invest their money

in them (notwithstanding the fact that the
a rule, hates to pay toll); for people will
they can, and generally in the quickest way.
tition between a bridge and a ferry, the latter,
convenience, sooner or later has to succumb;
can usually be made lower than the ferry charges
of expense of operation, which is far greater for a
a fixed bridge.

Bridge projects may be divided into the follow
for

Steam railway traffic,
Electric railway traffic,
Wagon traffic, and
Pedestrian traffic.

Very often, though, two or more kinds of traffic are
same structure, and in some cases a single bridge
four kinds. Generally, the more kinds of traffic that
ter the enterprise will pay; but there are, of course,
rule.

Projects for steam railway bridges are generally
of wealthy men who see the necessity for carrying
railroad across a large river so as to develop a
by railways. These far-sighted individuals usually
before investing their money to make provisional
of years with certain roads to use their bridge at
ducing the risk of loss to a minimum. Such an
ways be made, if it be possible, in the inauguration
enterprise.

Electric railway bridge projects are generally
building the railways, but sometimes they are
enterprises, mainly with the object of renting to other
the privilege of using the structure. In some cases
may appear quite attractive while the railway project
the only way for the company to get its bridge may
separate undertaking.

Wagon bridge projects are evolved in
urgent necessity for crossing some stream and
to pay fair tolls for the privilege. Generally it is
or city to build such a bridge; but there are
sary public money is not available and where
cases the building of the structure will be pretty
venture, especially if the company be granted an
the river within certain limits for a certain term
oly is often difficult to obtain, because it is
policy of open competition; nevertheless, when

[illegible] way to secure the desired structure than by [illegible] privilege demanded, they will succumb to the [illegible] promoters then must investigate the state laws with [illegible] as to make sure that their charter or franchise is [illegible] after the bridge begins to pay good returns on the in- [illegible] other company may succeed in having the old charter [illegible] and in obtaining another to build a rival structure.

[illegible] it is apparent that for many years to come there will [illegible] danger from the establishment of a rival bridge project, [illegible] the fact that almost no good bridge scheme is started [illegible] some insignificant imitator trying to raise the money to build [illegible] structure. Such action is both foolish and reprehensible, for [illegible] the double attempt is sometimes to kill both projects; and [illegible] community is left without a much-needed means for transporta- [illegible] is no one in the world more timid than a capitalist; and [illegible] very simple matter to kill a meritorious enterprise by start- [illegible] before the necessary capital is secured; and when once [illegible] been rejected by bankers of good standing, it is exceedingly [illegible] long time to revive it and raise the requisite funds for its [illegible]

[illegible] building pedestrian toll-bridges are rather rare, because [illegible] calling for them do not often exist. Generally, if there is [illegible] the accommodation of pedestrians, there is also a need for [illegible] The only places suitable for toll structures to carry foot [illegible] are those where wide, deep gorges or rivers have [illegible] where the money is not available for an expensive bridge. [illegible] the suspension bridge is generally the most suitable [illegible] is the cheapest type for long spans to carry light [illegible]

[illegible] to be taken in the promotion of a bridge project [illegible]

[illegible] should investigate personally the possibilities [illegible] keeping his own counsel about what he is doing, [illegible] himself from the swarm of blackmailers, leeches, and [illegible] business of fastening themselves upon any one who [illegible] conceive a good enterprise and the courage to un- [illegible] this investigation of conditions, he should, if [illegible] kind or kinds of traffic his bridge ought to pro- [illegible] amounts thereof that there will be, both at [illegible] series of years.

[illegible] step to take is to go to some reliable bridge special- [illegible] upon to treat the matter on a strictly confidential [illegible] make an inspection and survey of the proposed [illegible] estimate of cost, based upon the data that [illegible] great an expenditure of money and without

running much risk of exposing the project to the curiosity of persons who may have rival interests. If this bridge engineer is to be connected with the project throughout its entire materialization, he should be one who has had dealings with bankers and is familiar with their point of view and their attitude toward promoters and new enterprises. Such an engineer could be of much service in making the project presentable.

If the promoter has not been able to make up his mind finally as to the kind of traffic for which he ought to provide, he can now do so with the assistance of his engineer, who will tell him approximately the cost of structure to carry any kind or combination of kinds of traffic, and who will aid him in estimating the probable net revenues therefrom.

Third. After settling the questions of what traffic to provide for, the approximate cost of structure, and the probable net revenue, unless the promoter be a man of great individual wealth, which is extremely improbable, the next step for him to take is to form a company of a few trustworthy friends who possess means to aid him, and have the company take all the necessary legal steps to secure the right to bridge the stream and whatever exclusive privileges it is practicable to obtain.

The formation of a stock company for promotion purposes and to hold title to any assets that may be acquired during that stage of the enterprise has considerable advantage over the partnership form of ownership. The consent of all parties in a partnership is necessary for transferring assets, while in a stock company a majority vote of stock ratifying the action of the Board of Directors is sufficient.

Fourth. Next, the same engineer, or some other one, should be retained to make borings to bed-rock, if there be any at the crossing, or else to a suitable substratum, and from them to determine very closely the cost of structure, based upon current prices of labor and materials, but allowing properly for such contingencies as a possible rise in the material market or an increase in the cost of labor. He should also be required to make a layout to submit to the War Department for approval, if the stream be navigable. These various steps will ensure to the promoter or his company the control of his project from a legal standpoint, which is a *sine qua non* in dealing with capitalists.

Fifth. The next step, and one of the most important, is the preparation of a prospectus. Upon the manner in which this is done will depend the success of the undertaking. The promoter should remember that his project may have to compete with many others for investment-capital and that the demand for this far exceeds the supply; hence his prospectus should be prepared in such a manner as to appeal to the banker from the start and hold his attention in order to win him over and away, perhaps, from other projects that he has under consideration. The requisites for a successful prospectus are honesty, moderation, thoroughness, clearness, conciseness, and a conservative amount of enthusiasm.

Setting aside the moral question involved, honesty is an absolute

[illegible]

[illegible] prospectus, it would be folly of the [illegible] by an unduly favorable statement of the [illegible] of first cost or of maintenance, or too high [illegible] are essential in a prospectus, because bankers are [illegible] flights of fancy of the ordinary promoter to be deceived [illegible] or rosy-hued statements.

[illegible] is a necessity, for without it the presentation of the [illegible] and its lack will cause serious doubts in the bankers' [illegible] the ability of the interested parties to handle the project. [illegible] requisite not only to ensure the reader's understanding [illegible] but also to produce a favorable impression on their [illegible] strings. A well written document invariably carries [illegible] means of its correctness of style and its elegance of diction. [illegible] is necessary, because a busy banker will not take time to [illegible] a long, verbose statement which shows upon its face the [illegible] writer concerning this prime requisite of financial documents.

[illegible] controlled enthusiasm is also an essential for a prospectus; [illegible] the promoter is optimistic about his project, nobody else [illegible] he succeeds in stirring up a certain amount of enthusiasm [illegible] will fail to materialize.

[illegible] prospectus should begin by stating as concisely as possible [illegible] affecting the business of the proposed structure and the [illegible] location at a certain place. Then it should proceed to [illegible] history of the development of the enterprise, and should [illegible] the principal parties in interest and their standing in the [illegible] name of the company's engineer should be given, be- [illegible] in accepting or rejecting a proposition is often [illegible] is the engineer retained by the promoters. The [illegible] should be fully described, and the amount of its capital [illegible] stated. Next should come a short description of the [illegible] complete detailed estimate of its cost, immediately fol- [illegible] should be a statement of the amount of actual cash [illegible] enterprise, including a certain sum to put the company [illegible] of operation for a year or two after the bridge is [illegible] should come a detailed estimate of annual cost of oper- [illegible] depreciation, repairs, interest, taxes, and all other [illegible] This should be prepared by one who is conversant [illegible] the management of such an enterprise and of the [illegible] the figures given will have to be verified by the [illegible] contract will be entered into to underwrite [illegible] the necessary capital. Next there should be [illegible] estimate of revenue, complete and reliable, based

upon premises which are ind
is beyond adverse criticism. Following th
ment of the estimated net revenue of the
profits to the stockholders of the company,
it is well to give a succinct résumé of the prec
culations and a concise presentation of the
sure to prove profitable to the investor. If the
one, it is advisable to precede it with a short syn
be stated very concisely the *raison d'être* of the
expected to accomplish. The object of such a syn
catch quickly the capitalist's attention and arous
sufficiently to induce him to read the whole prosp
of such a synopsis, if it be judiciously prepared, cannot

Sixth. The next step to take is for the promoter
other influential member or members of the compan
to submit the prospectus, maps, drawings, and other
is often well to have the engineer accompany the
way, should seldom be large, because a small com
do business much more expeditiously than a large
in choosing the bankers first to be approached. Th
ists who are accustomed to handling bridge projec
at the time too busy in financing other schemes.
enterprise should aid in determining the bankers
for certain capitalists deal only with very large
those of moderate size, while many are of
with small ones.

It is almost an essential that the parties in inter
well introduced; for often capitalists refuse to rec
tunately, this introduction occasionally costs either
of stock or some other recognition of services that
ture of some of the promoter's money. One seld
value for nothing; hence the promoter must not
he finds that an introduction to the financial powe
well, though, for him to make such a remuneration
bankers' undertaking the financing of the projec
transaction to a perfectly legitimate one of broker

In dealing with bankers the promoter should
time as possible. They are busy men and cannot
minutes of their working hours. When the pro
let him leave his prospectus and papers, ask for
pointment, and bid the capitalists good day.
this hint, he will very quickly be given his *cong*
consequently it is just as well to avoid such a

The inexperienced promoter almost invaria
with great notions of how he will handle the

the law to them and permit them to join forces with him in his important undertaking, and how he will concede to them a small percentage of the capital stock and keep the bulk of it for himself and his associates; but after he has once put through a project, or even has tried to do so and failed, he will have become a sadder but a wiser man. He will find that it is the bankers who dictate terms, because enterprises requiring capital are brought to them every day, and from the numerous ones presented they can pick and choose, and that it is they who will take the lion's share of the capital stock and leave a small percentage for the promoting company. Those who seek capital for an enterprise must go prepared to submit to many disappointments and reverses; for financing of projects is no easy matter. Bankers are difficult men to deal with, and they have the whip hand. Moreover, one cannot count upon their doing what they promise or agree to verbally, until they bind themselves in writing, as some of them make a practice of agreeing verbally to underwrite a project, then, if before confirming the agreement in black and white something more attractive is submitted, they feel at liberty to change their minds. On the other hand, though, if they find that a promoter is trying to deal simultaneously with two sets of bankers or capitalists, they will turn him down with great indignation because of alleged lack of good faith.

Should the first capitalists approached reject a proposition, it is often difficult to induce others to entertain it; and after it has been hawked around for a while among various bankers it might as well be abandoned, because it will have gotten a bad name,—and that is almost certain to kill it. Financiers term such projects "footballs." Of course, the first or even the succeeding bankers approached may not be in position to underwrite the project on account of other business; and in such a case a polite request from the promoter not to mention the fact that he had submitted his scheme to them may prevent any ill effects from the unsuccessful attempt or attempts; but a rejection of a project by prominent bankers on the plea of its being of an unsatisfactory character is generally its death knell, because the leading financiers of the large cities meet often and exchange confidences, and there are close, intimate connections between the banking houses of the principal cities. In order to avoid the danger from publicity of one's project, it might be feasible in some cases to have a mutual friend, or some other disinterested person, interview the banker before he is formally approached and sound him as to whether he would be likely to take an interest in an undertaking along certain general lines, without giving him any information which would enable him to locate the enterprise or to discover the names of the parties interested.

If a banker consent to back a project, he will generally demand an option on it for a few weeks or months in order that he may confer with other bankers and obtain their aid in the underwriting, especially if the undertaking is a large one; for the reason that bankers usually act upon

the old established principle that it is not well for one to carry all his eggs in one basket. They prefer to share both profits and risks with their brother bankers. Moreover, it is easier to dispose of the bonds to the small buyers when the issue is largely divided, especially when it is underwritten in several cities.

Bridge bonds are commonly taken by the underwriters at a rather heavy discount, the price for five (5) per cent bonds being often as low as eighty-five (85) cents on the dollar. In addition they demand as large a share of the stock as they think they can squeeze out of the promoters, and this, as a rule, remains in their hands; for it is their custom to sell the bonds to their clients in small amounts at a price about ten (10) cents on the dollar higher than the underwritten figure, and not to give them any of the stock, if they can avoid doing so.

The amount of the bonded indebtedness is ordinarily made large enough to ensure sufficient actual cash to build the structure complete in all its details and to leave a small amount in the treasury in order to provide for a possible deficit in earnings during the first year or two; but sometimes the financier insists that the promoters buy a certain amount of the stock at a small figure, say twenty-five (25) or thirty (30) cents on the dollar; and thus the amount of the bonded indebtedness is reduced. In the preliminary organization of the company and when making the financial arrangements, it is a wise precaution to provide for a possible future increase of bonded indebtedness as well as for an enlargement of capital stock. The amount of the latter at the outset is arbitrarily fixed, and it is of small importance, as it usually represents nothing but water. However, the ordinary arrangement is to make it equal to the amount of the bonded indebtedness. In most cases all the stock is common, but sometimes a portion of it is preferred. If the prospective net profits are small, the preferred stock is the choice kind; but if they are very high, the common stock is the better, as there is no limit to the profit which it may pay, while the preferred stock carries either a fixed or a maximum rate of interest.

If an engineer acts as a promoter or gives much of his time to aid the promoters in financing, he is entitled to a portion of the stock, unless his services are fully paid for either in cash or by an agreement according to which he secures the future engineering of the designing and construction.

Generally, it is not a good thing for a bridge engineer to make a practice of promoting enterprises on his own account. It is far better for him to be retained by the promoters to aid them in their work. The possibilities of large profits and the element of gambling involved in such occupation are very attractive to some minds; but experience shows that the bridge engineer will generally succeed better in the end, if he confines his attention and energies mainly to professional duties and leaves to men of less education the pioneer work of promoting. Nevertheless, there may come occasionally to a bridge engineer an opportunity either

[illegible]

[illegible] such a case, if the engineer be a [illegible]
[illegible] it may be advisable for him to undertake [illegible]
[illegible] doing so he should call to mind the old proverb
[illegible] a slip between the cup and the lip" and try to [illegible]
[illegible] difficulties, backsets, disappointments, and [illegible]
[illegible] to be almost inevitable in the materialization of great
[illegible] decide whether "the game is worth the candle." [illegible]
[illegible] can occasionally be materialized by securing [illegible]
[illegible] city a guarantee of the principal and interest of the
[illegible] is feasible only when the projected bridge is a great public
[illegible] such a case the guarantee is likely to carry with it the
[illegible] guarantor will have the privilege, after the expiration
[illegible] of buying the structure either for a certain fixed sum
[illegible] to be made by a commission at the time of purchase.
[illegible] standpoint this proviso is an objectionable feature,
[illegible] the bonds more difficult to sell; but in most cases
[illegible] guarantor will ever avail himself of the privilege is
[illegible]

[illegible] the promoter to keep secret all his financial operations,
[illegible] to purchase or condemn right of way; and the mo-
[illegible] that he has secured the money for his enterprise, up
[illegible] of everything that he has to buy. It is well, if possible,
[illegible] of any financial negotiations long time options on
[illegible] to determine or have waived beforehand all dam-
[illegible] in the vicinity of the proposed structure; but often
[illegible] unable to raise the cash required to pay for such options,
[illegible] that the chance of ultimate success is too small to warrant
[illegible] money.

[illegible] investigations concerning the probable traffic and
[illegible] revenue should be made with great care and conserva-
[illegible] is optimistic by nature is prone to overestimate, and no
[illegible] account at all unless he is more or less optimistic;
[illegible] consider very carefully all uncertain matters connected
[illegible] estimates, and should endeavor always to err upon the
[illegible] Similarly, in computing the annual cost for maintenance,
[illegible] like expenses, he should be careful to omit no items
[illegible] high enough to be beyond criticism. In the chap-
[illegible] are given lists of items of both first cost and operat-
[illegible] will be found quite useful to the promoter of bridge
[illegible]

[illegible] their estimates of cost and maintenance make a
[illegible] liberally for contingencies; but to the author
[illegible] acknowledgment of weakness or lack of experience;
[illegible] each case should be so complete that not even a

[illegible] is omitted, and the
be about right. Therefore, if the
careful, he may either omit the item of
reduce its amount to an insignificant figure.
chapter on "Estimates," one is going to allow
it is better to do so in a single item instead of
to each item on the list. If the latter method is
too often be an excessive total allowance to
tainty. While the author is of the opinion that
for an engineer to allow too liberally in an estimate
recognizes the fact that *the non-professional promoter*
an engineer, should pursue an entirely different
serious future difficulties caused by too small an

In trying to obtain any franchise or charter
to make too many rash promises and to agree to
for influence and other aid, with the result that
necessary later on to buy back such gift stock,
It is good policy to incur as few such obligations
it one's invariable practice to put all agreements in
on there shall be no quibbling about amounts
rendered. If a promoter is in the habit of making
writing, and if any one attempts to blackmail him
motion, as too often happens, the rascal will find
firmed habit of recording agreements and his own
written contract will so militate against him
he will lose his case and fail totally in his nefarious

CHAPTER LXXIV

BRIDGE ENGINEERING FEES

generally conceded fact that the engineering profession on the underpaid, for while the young engineers fresh from the technical command larger compensation than the recent graduates in law their earnings do not increase proportionately with their knowledge and experience, so that after one or two decades behind the men of their own age in the other professions. But comparing the earnings of those who have reached the summit that the engineering profession makes the poorest show-leading lawyers, physicians, and surgeons demand and obtain their services, and there are many of them to be found in of America; but only a very few prominent engineers salaries or large fees, and the amounts of their compensation those of the shining lights in the other professions. This because no one has to study more faithfully for his degree in practice to attain success than the engineer. More-the world's work is more important than his, for it is a gen-acknowledged fact that the whole progress of humanity depends his efforts.

the reason for this unsatisfactory state of affairs, and upon blame? Possibly it is because engineering has only lately as one of the learned professions; but it is surely old have developed sufficient influence with the public to obtain compensation for its members. As for where the blame lies— one answer to the question, viz., upon the engineers them-If an engineer of good standing and education makes a practice for a mere pittance, is it likely that people will pay him more is accustomed to accepting? Again, the unprofessional engineers, that, alas, is by no means uncommon, is degree for the meagreness of technical men's com-engineers develop in themselves a love and respect for a desire to advance it by every legitimate means in unsatisfactory conditions will continue, and the engineers in general will continue to remain in the

individual engineer do to advance the status of it to a higher plane in public estimation? The one. Let him refuse to lend himself to every

endeavor on the part of his clients or employers to keep down the salaries of his subordinates; but, on the contrary, let him insist upon their compensation being advanced as their experience and the value of their services increase. Let him also refrain from envy and ill-natured remarks when he learns that some other engineer in his own class has received advancement or has secured a large fee; but, on the contrary, let him tender his more fortunate brother hearty congratulations; and when he loses a piece of work in competition let him congratulate the employers upon their having secured such valuable services instead of making some ill-natured, sneering, or derogatory remark. Let him also be on the lookout to advance those of his friends in the profession who are worthy of advancement, by recommending them for positions which he knows are to be filled; and let him always be willing to allow any of his assistants to leave his service when they are offered (or when he can find for them) better compensation than he or his principals can afford to pay. Will such a course of procedure tend to hold back his own advancement while others are pushing ahead? Far from it. On the contrary, it will make him so respected by the community in general that his ultimate advancement will be assured.

Certain bridge engineers have established for themselves schedules of charges, and they try to live up to them; but in many cases they are forced either to vary from them or to lose the work. The following is an average schedule of minimum fees for bridge engineers of established reputation:

For the entire engineering connected with the designing, manufacture, and construction of a large bridge, exclusive of the inspection of metalwork at mills and shops, five (5) per cent of the total contract cost of the completed structure, including substructure, superstructure, and approaches, or five and a half (5.5) per cent if the bridge contain a movable span. This is exclusive of the preliminary study of the crossing and the making of borings.

For plans, specifications, and estimates for a large bridge, three (3) per cent of the estimated total cost of substructure, superstructure, and approaches, based upon current prices of materials and labor, or three and a half (3.5) per cent if the bridge contain a movable span.

For plans, specifications, estimates, checking of shop drawings, and inspection of metalwork at rolling mills and bridge shops for a large bridge, three and one-half (3.5) per cent of the total cost of substructure, superstructure, and approaches, or four (4) per cent if the bridge contain a movable span.

For the field engineering alone of any large bridge, the actual cost of doing the work plus either a fixed sum or a monthly salary.

It almost goes without saying that one must charge higher percentage fees for small structures than for large ones, because many of the expenses are just as high in one case as in the other. It is hard to say where an

[illegible]

[illegible] the volume of his business and [illegible] ladder. What would be a large [illegible] be deemed a small one by another of [illegible] practice. The author considers that any [illegible] two hundred thousand dollars ($200,000) [illegible] fees exceeding those he charges for more [illegible]

[illegible] study of a proposed crossing with an estimate of [illegible] the expense for making borings, one-half (½) of [illegible] estimated total cost.

[illegible] of superstructure metal at mills and shops, [illegible] cents ($1.25) per ton of two thousand (2,000) [illegible]

[illegible] inspection with supervision of loading of metalwork on [illegible]portation, one dollar and fifty cents ($1.50) per ton.

[illegible] borings to and into bed-rock, the actual cost thereof, [illegible] sum or a salary commensurate with the amount of [illegible] involved.

[illegible] of and reporting upon old structures, the actual cost [illegible] or plus a per diem fee of from fifty (50) to one hundred [illegible] in the case of a great many bridges to be examined [illegible] thirty (30) cents per lineal foot and all traveling expenses.

[illegible] testimony, not less than one hundred dollars per day and [illegible] including time spent in traveling), and as much more as [illegible] importance of the work or the value of the said testi[illegible]

[illegible] of and reporting upon an existing bridge, one (1) per [illegible] value, unless it be a very large structure, in which [illegible] be materially reduced, with a minimum limit of one-[illegible] per cent.

[illegible] in addition to the entire engineering on a bridge [illegible] construction is done by day labor or at cost plus either [illegible] percentage for profit), the percentage for the engineering [illegible] about one and a half (1½), the size of the in[illegible] upon the magnitude of the work, the larger the structure [illegible] increase.

[illegible] clients and to attorneys in law suits the fee must be [illegible] amount of the money involved and upon the special [illegible], as no hard and fast rule will apply to this class [illegible]

[illegible] the compensation must be adjusted to the [illegible] under discussion and to the amount of money [illegible] saved for his client.

[illegible] engineer to prepare standard plans for bridges

and in force even the said plans
within so as many structures as he may
than the ordinary should be made; because
plans for a bridge, no one has a right to use
permission for any other structure than the
stated. In the author's opinion, the fee in this
twice as great as that which would be charged
only once. Engineers, for the benefit of the
courage all they can the preparation of such

For the designing of a movable span alone, the
higher than that charged for the designing of
a swing bridge the percentage should vary from
for a bascule or vertical lift bridge it should run
and the cost of the substructure should be included
is applied. The designing and detailing of machinery
pensive work, and there is a great deal of machinery
movable spans; besides, the structural metalwork
plicated than that for fixed spans· hence the
designing should be greater.

If a bridge engineer of established reputation is paid
any work, he should seldom make his daily charge less
dollars ($100) and all expenses, unless he be promised
the engineering of future construction. Under such
be perfectly proper for him to halve his per diem fee.
traveling for clients should be paid for on the same basis
on actual work.

When an engineer is retained to do important work
curing a valuable charter or concession, and when it is
sional standing and reputation that success depends, he
other inducements than the standard fees or per diem
wise he would simply be pulling his client's chestnuts
it is mainly upon his ability and reputation that the
tempt depends, he surely should be given an interest
tained through the concession; and it is perfectly
drive as hard a bargain as he can with his clients

It is not right or politic for a client to force a
out of his fee the expenses of making borings, because
ing in advance, even approximately, what such
far better for the client to let the engineer spend
is required to secure all the necessary information
or other foundation; because, ordinarily, every
such data involves several dollars saved on the
fectly legitimate and proper for an engineer to
for preliminary work be absorbed by the later
struction, in case that the project be a large

himself and the profession to avoid doing so, if possible. In general, it may be stated that the more an engineer demands for his services the more highly will he be appreciated by the public. Of course, he may sometimes lose a piece of prospective work by holding up his charges; but eventually he will be the gainer thereby, and he will certainly have the satisfaction of knowing that he has done his share to raise the engineering profession to a higher standard.

There is but one case where it is right and proper for a bridge engineer to cut rates, and that is when his client is a brother engineer or an architect, and when the said client has to pay the consulting fee out of his own compensation. Under these circumstances the lower the consulting engineer makes his charge the more worthily does he act; and it is often eminently proper for him to reduce it to zero. He should beware, though, of falling into a trap in such a case; because occasionally a sharp promoter has been known to endeavor to save a consulting engineer's fee by ordering his own engineer to ask for assistance and advice under the false assumption that it is to be paid for out of the said engineer's salary, which is too often a mere pittance.

CHAPTER

SOME BUSINESS FEATURES OF

Although engineering is now
sion, it cannot be denied that there is a
with it, and this is specially true of
tion with the client's work and with that of
moter that this chapter is concerned.

The organisation of a bridge engineer's office
them continually occupied, and arranging
adequately and regularly, demand business
he who does not possess it would do well
as a consulting bridge engineer. Again, in
unprofessional for a lawyer, is by no means
dealing with prospective or actual clients, the
the ability and *savoir faire* to make a good
see that he understands his vocation in every
and this involves the possession of sound

It is in negotiating with prospective clients
projects that an engineer most requires
does not exercise firmness and sound judgment
nary financial arrangements, he may later find
of his time but also out of considerable cash.
pecunious, and hence are likely to try to make
sulting engineer for the preliminary work based
liberal compensation. It may be all right for the
such a proposed method of doing business; but
insist upon tying up the parties by a hard-and-fast,
cording to which, in case the project is materialised
to do all the engineering thereon at certain fixed
neration. Again, he should make sure that he
to put any of his own cash into the affair; but
starting his operations the parties deposit a
his credit to be drawn upon from time to time
sistants and others for doing the preliminary work
sure that more money will be forthcoming when
but not quite exhausted. If he can secure
as the work progresses, let him do so by all
generally the promoters prefer to pay him in the
money. If the project be a good one, it is

[illegible] payment therefor should be [illegible]
[illegible] a doubt.
[illegible] with promoters, if they have already formed [illegible]
[illegible] the agreement should be drawn with it instead of with them
[illegible] and it should always be made binding upon its successors or as-
[illegible] sharp trick sometimes practised to try to repudiate [illegible]
[illegible] out nominally to other parties. If the engineer [illegible]
[illegible] agreement will use the author's little book entitled
[illegible] Specifications and Contracts," and will apply properly the
[illegible] given, he will be able to protect himself adequately
[illegible]

[illegible] engineer agrees to risk his personal time to aid in the
[illegible] enterprise, he ought to secure a future fee larger than
[illegible] the work involved, in order to compensate him for the
[illegible] reasonable man can object to a demand of this kind. As
[illegible] of the increase—that would entirely depend upon how
[illegible] would be likely to be needed for materialising the
[illegible] the magnitude of the construction. Probably from
[illegible] to fifty (50) per cent would suffice for most cases.

[illegible] is asked to take some of his compensation in se-
[illegible] is where his business judgment comes in; for if he
[illegible] to offend his principals, and if he accedes, he runs
[illegible] unsalable and valueless paper left on his hands. He
[illegible] in his own mind how badly the promoters need his
[illegible] they have any other engineer in view for the work, then
[illegible] he will take any securities, how many, and at what
[illegible] generally pretty safe to accept, especially at a discount,
[illegible] which promoters are in the habit of offering. They
[illegible] which is worth ordinarily only a few cents on the
[illegible] the structure is finished and utilized for traffic.
[illegible] it is well when accepting them to insist on some
[illegible] as a bonus.

[illegible] the bridge engineer should endeavor to main-
[illegible] dignity of the profession, for instance, by patron-
[illegible] by spending his money as a gentleman should.
[illegible] of an engineer which savors of the picayunish
[illegible] unfavorable not only to him personally but also
[illegible]

[illegible] a bridge engineer treats his employees is an
[illegible] business ability or the lack of it. He should
[illegible] assistants, and should pay them all that their
[illegible] best method of securing good men is to take
[illegible] technical schools, train them, and pay them

according to what their services are worth, dropping ruthlessly those who are idle, incompetent, or otherwise undesirable. He should take a strong, personal interest in the welfare, development, and advancement of those assistants who give promise of becoming good engineers, and should aid them in every way that lies in his power. Such a course involves not only good engineering ethics but also good business.

He can save himself and his principal assistant engineers much trouble and the office much expense by selecting with care the recent graduates whom he employs. Their instructors in the technical schools can usually give him a very good idea of their ability, industry, and individual peculiarities; and it is well for him to keep in close touch with the professors of those technical schools from which he draws mainly for assistants.

A bridge engineer should insist strictly on regular attendance of all assistants to their work in both office and field, and should so organize his forces that this *desideratum* will be assured. Each assistant should be made to endeavor at all times to produce the maximum amount of useful daily work of which he is capable. The office work should be so laid out that there will always be some valuable routine occupation ready, in case that the ordinary tasks run short. Such an arrangement assures that nobody's time will be wasted for want of something to do, provided that the head of the office allots properly the routine work to the various subordinates. Working hours for office men should be from 8 A.M. until 5.30 P.M., or 6 P.M. with an hour off for luncheon; but in extremely hot weather and when work is not unusually pressing, a half-holiday on Saturday should be allowed, making the hours for that day from 8 A.M. till 1 P.M.

Each employee should be annually granted a two weeks' vacation on full pay. Every man who labors hard is entitled to a short period of rest each year, in which to recuperate his forces and relax his mental strain. By taking such a vacation he will accomplish more useful work annually than he could by continuous labor. The employer, however, should make sure that the vacation period is spent in relaxation and not on work for some one else or in study.

As a matter of business, it is well to pay office men for overtime at their regular rate of hourly compensation, but from such extra earnings should be deducted the value of any time that may have been lost. On the other hand, it is not advisable to dock a good man's salary because of a little unavoidably lost time, unless there be something due him from overtime. But it is not good business to make a practice of working one's employees overtime; however, occasionally it cannot be avoided, especially when there is a piece of work that has to be finished quickly. One cannot obtain effective labor from tired men, and if a practice be made of having the employees work extra time, they will get into the habit of dawdling during the regular working hours in order to enlarge their monthly earnings by overtime occupation. Every field-man's time should

be fully occupied in attending to his regular, routine work, which should be so laid out for him in writing that there will be no excuse for shirking. As there is a good deal of standing around during construction hours for the field engineer, he should not object to giving some portions of his evenings to routine work, such as making notes in his diary and preparing his reports. There should be no overtime allowed for field engineering work.

It is a wise precaution either to carry accident insurance for one's field forces, or to have it understood in writing that a certain small portion of each one's salary is paid him for the purpose of insuring himself, if he so desires; and that if he does not do so, he will have no claim against his employers because of any accident that may happen to him. An engineer should insure his office outfit against fire for as high a figure as the insurance companies will agree to; and even if he does so and is burned out, he will find that he is decidedly out of pocket after the loss has been settled. One cannot insure records at anything like their value, hence it behooves a bridge engineer to have an office in a building that is truly fire-proof.

It is not a bad plan for a bridge engineer to give two or three of his principal assistants a small interest in the annual profits of the office which are in excess of a certain fixed amount; but the advisability of treating the rank and file of the assistants in the same way is problematical. Owing to the fluctuation in the amount of work in both office and field, a bridge engineer, of necessity, must employ more or less floating draftsmen and inspectors, whose services may be dispensed with at any time; and there is no need to let such men share in the profits of the business.

When bad times strike the bridge engineer, he should not make the mistake of discharging all of his men in order to cut down expenses, but he should evolve routine work to keep his best assistants busy until paying work is resumed. If he does not do this, he will find that when the period of depression has passed, he will be unable to do even a small portion of the work that he could readily secure. During good times he should save and lay aside money for the special purpose of carrying his well-trained men, or a good number of them, through the next period of depression.

It is true economy for a bridge specialist to pay a good price for shop inspection, provided that by so doing he makes sure of obtaining it. Cheap inspection is a cause of endless worry and annoyance; and sometimes it entails serious loss to one's clients. One can ensure the best results by keeping constantly in his employ several trained inspectors who are accustomed to his methods and who know how to obtain good shopwork from the manufacturers; but the payment of their salaries when they are not employed is a heavy tax on his resources. It is generally cheaper for him to let out his metalwork inspection to a good in-

[illegible] pay for inspection, [illegible] requires it to be done. This is [illegible] and it is due entirely to the pernicious [illegible] by competition.

CHAPTER LXXVI

RESPONSIBILITY OF THE BRIDGE ENGINEER

[illegible] member of society who is called upon to shoulder more [illegible] than the civil engineer, and of all the specialties in engineering none involves more than that of bridgework; for the man who [illegible] a bridge is responsible for the life of every one who crosses it from [illegible] it is finished until the day it is taken down. It is true that the [illegible] a bridge grows the smaller becomes the designer's moral responsi- [illegible], because the structure is liable to deterioration [illegible] and the loads to which it is subjected may be so increased as [illegible] those for which it was designed by more than good practice [illegible] In such a case the moral liability of the designer should really [illegible] by the engineer who looks after and operates the structure; [illegible] if any accident befall it, the first question asked is, "Who [illegible]?" and most of the blame naturally falls on him.

[illegible] responsibility for the safety of the people and the property [illegible] his designs is not the only serious one with which the con- [illegible] bridge engineer is burdened; for he is liable (at least morally) [illegible] errors and mistakes of his various assistants; he is generally [illegible] his structures cost more than he estimated or if they are not [illegible] time; he is called to account (and very properly) if the [illegible] do his work correctly or give the client his money's [illegible] is often censured if any serious accident to men or materials [illegible] construction; and he is usually either blamed by the con- [illegible] severity or by his client for being too lenient. In [illegible] engineer's life "is not a happy one"; nevertheless it has [illegible], for the satisfaction experienced from the successful [illegible] great structure built under unusual difficulties offsets [illegible] anxiety caused by heavy responsibilities.

[illegible]'s responsibilities may be divided into three classes, [illegible], and moral. The legal ones are more imaginary [illegible] the courts would never consider as a criminal an en- [illegible] work a serious accident had occurred, unless it could [illegible] due to maliciousness on his part, which is prac- [illegible] no sane man would wilfully cause an accident which [illegible] a slur upon his own professional reputation, even if [illegible] never be discovered. In case a bridge engineer [illegible], and the matter were brought to court, no [illegible] suggest punishing him for his fault, because

they would feel that his loss of prestige and the griping of his sorrow and remorse would be far greater punishment than any they could inflict.

Nor is a bridge engineer's financial responsibility much greater than his legal, because generally he is by no means a wealthy man. If there were an accident on his work which was proved to be his fault, or if his designs were bad or his calculations erroneous and his client suffered loss thereby, it would be difficult for the said client to recover from him pecuniary damages, primarily because he would not have the money to pay them unless they were quite small, and secondarily because to err is human, and on that account the judge or jury would consider that the client in choosing his engineer took the precaution to investigate his reputation and that, if any mistake were made in the selection, the client alone was to blame.

But the moral responsibility is the one that counts, and it is far heavier than either of the others could possibly be. What greater punishment can be imagined for a conscientious engineer (and nearly all bridge engineers are such) than to have perpetually overshadowing him the depressing thought that through his ignorance, carelessness, or lack of forethought human lives have been lost and valuable property destroyed! The remainder of his life would not be worth living. Far better for him would it be to go down to death with the other unfortunates on his structure!

That this sentiment is a true one was once proved by a certain bridge engineer who was finishing for another member of the profession the repairs to an old structure which carried the main line of an important railway system across a great river. Finding one of the new wrought-iron counters to be too short and therefore only partly effective, he conceived the idea of lengthening it by placing a riveting forge beneath the short end, heating a portion of the bar, pounding upon the metal and at the same time rotating the turn-buckle, and thus stretching the piece. Accordingly he gave orders to the foreman one night to get everything ready, but not to start the fire until his arrival in the morning. Next day his train was late, and the foreman (becoming impatient) heated the bar, twisted the turn-buckle without pounding the metal, and broke the rod, which stretched and parted as would a piece of molasses candy. The deed was done and the damage had to be repaired with the least possible delay; consequently the engineer and the foreman sat down on the deck and evolved jointly a false turn-buckle which could be manufactured in a near-by town and attached in a crude but effective way without the necessity for falsework—that which had been used for the reconstruction of the bridge having been removed. Unfortunately, this repair work demanded time, and a passenger train was due a few minutes after the design was evolved. The engineer felt confident from his general knowledge of bridge superstructures that the other counter of the pair would do the work of the two, but he could not prove it by figures. It was then up to him to decide whether he would block all traffic on the

[illegible] twenty-four hours or risk the lives of the [illegible] train. Relying upon his engineering judgment, he [illegible] and ordered the foreman and all his men off, [illegible] stood himself by the broken counter until the train had [illegible] the possibility of death to that of professional disgrace. [illegible] was justified by the safe passage of the train; and by the next [illegible] broken piece was repaired. That was more than a quarter [illegible] ago, and the crude turn-buckle has been doing effective service [illegible]

[illegible] engineer having much practice employs a large force of [illegible] who are more or less expert; and it is impossible for him to [illegible] every detail of their work and make sure that it is right. [illegible] he can do is to train all his men on general principles and so to [illegible] forces and their work that only well equipped men will be [illegible] important tasks, and that every design will be checked in [illegible] independent computer. Even with the best possible organ[illegible] errors will occur, and it is possible that some of them will [illegible] until they enter the actual construction, or that some [illegible] in the shops by their correction. The question then [illegible] who should stand the extra expense involved. Legally it [illegible] be the client; but morally it is the engineer. In the few [illegible] which have arisen in the author's practice he has paid the [illegible] taken the opportunity to lecture severely not only the [illegible] responsible for the errors, but also the whole office [illegible] sometimes felt that the moral effect of the practical evi[illegible] of carelessness was worth the expenditure for the repairs.

[illegible], the amount involved were large (for instance, if [illegible] fall), and if the engineer were not really to blame, it [illegible] hold him pecuniarily responsible, because the value [illegible] is altogether too small to warrant his guarantee[illegible] himself and his assistants. All that his client can expect [illegible] his level best—if that be not good enough, the fault [illegible] for not having made a better choice when selecting [illegible] work. This question is treated in a masterly manner [illegible] Hubbell, Esq., Chief Engineer of the Philippine Bureau [illegible] his findings are discussed editorially in *Engineering* [illegible] page 779. Mr. Hubbell says:

> [illegible] to hold the individual engineer financially responsible [illegible] error of judgment on his part may cost more than his [illegible] Nor is it customary in any part of the civilised world to [illegible] responsible. A captain loses his ship but he does [illegible] the loss, nor does he lose his standing as a captain unless [illegible] been negligent in his duties. The average lawyer [illegible] per cent of his cases; but he does not reimburse

[illegible]

[illegible] placed by the [illegible]
[illegible] of moral responsibility is [illegible]
[illegible] prepares plans and specifications [illegible]
to supervise the manufacture and erection. [illegible]
the client is apt to cast the blame upon the [illegible]
reality it should be placed jointly upon the [illegible]
inspector. A case of this kind arose once in [illegible]
which the client asked him to pay for the [illegible]
he (the client) deemed due to faulty design, but [illegible]
tended were caused by bad shopwork and in[illegible]
speaking, it is not right to try to make the design[illegible]
even if the fault apparently be his; and unless [illegible]
trouble encountered be traced beyond all possible [illegible]
would be unjust to load him with the moral respo[illegible]
his professional standing. There is no way to [illegible]
cept for the consulting engineer to refuse to pre[illegible]
be permitted to supervise the inspection, manufac[illegible]
but as his taking such a stand would be likely to [illegible]
prospective job, he would naturally be averse to [illegible]
run the chance of encountering the anticipated [illegible]

Occasionally a bridge engineer finds it [illegible]
his client, either to prevent him from doing some [illegible]
construction or to force him to treat his contractor [illegible]
such circumstances the engineer should stand out [illegible]
if the result be that he must resign his position. [illegible]
to dictate to a bridge engineer as to what materials [illegible]
type of design to adopt. The engineer should be [illegible]
materials that the market affords; and as for the [illegible]
he can sometimes give the client a choice of two [illegible]
the limits of good practice; but when an effort [illegible]
type which is unfit, the engineer should not only [illegible]
the question to the bitter end. The client may [illegible]
neer from all responsibility by giving him a state[illegible]
effect; but while he can thus absolve him legally, he [illegible]
because the engineer will always, in public opinion, [illegible]
for the structure which he has designed and [illegible]
though, some detail of construction objectionable [illegible]
not of grave importance is forced upon him. [illegible]
do is to protest in writing against the change [illegible]
his letter filed in safe places for his future [illegible]

[illegible] the bridge engineer to protect his position, [illegible] and either publish his letter at once or [illegible] of it for future publication.

[illegible] ordinary conditions, an engineer has no right to [illegible] how his work is to be accomplished, [illegible] expedient is about to be adopted, the [illegible] the contractor the danger, and if the latter [illegible] in writing, thus throwing the responsibility on him. [illegible] enough to jeopardize human lives, the [illegible] authority and forbid further progress until the [illegible] is either abandoned or so modified as to avoid the [illegible]

[illegible] happens that an engineer's client, either through [illegible] moral principle, attempts to take an unfair advantage [illegible] In such a case, although the engineer is the client's [illegible] he should insist upon the contractor's rights being recog- [illegible] his own position; for the engineer is the judge [illegible] all such cases, and it is his obligation to see that both [illegible] just dues. Sometimes such action lays the engineer [illegible] of collusion with the contractor; but the possibility [illegible] should not prevent him from doing what his conscience [illegible] Often by taking a firm stand he will be able either [illegible] to force his client to do the proper thing. A threat of [illegible] compel an unscrupulous man to abandon an unjust [illegible] contemplating. The bridge engineer should certainly [illegible] and should be possessed of considerable force of char- [illegible] be able to deal properly with all the moral and equity [illegible] sure to arise in a great practice.

[illegible] of the bridge engineer which is most recognized by [illegible] is that of ensuring that his structures are built strictly [illegible] the plans and specifications. To accomplish this is [illegible] for a successful professional career; and one should [illegible] construction that is not truly first-class, no matter how [illegible] is involved in obtaining proper work. Most bridge [illegible] build their structures in a creditable and workman- [illegible] some of them, when they anticipate losing money on [illegible] possible expedient for economizing, regardless of [illegible] resulting construction. Under such conditions the [illegible] it necessary to exercise the utmost vigilance, and [illegible] contractor to employ all the firmness of character [illegible] endowed him or which his worldly experience has [illegible]

[illegible] contract is let to an incompetent contractor or

tractor who is unwilling to do the work in
tions. In such a case, the engineer should
taking advantage of the clause provided for
properly written bridge specification, by
letting the work to other parties, and finishing
expense. But before employing this drastic expedient
his client's attorney so as to make sure that every
fectly legal manner, in order to prevent the con
damages later for loss of money or alleged injury

In order to forestall the contingency of having
dishonest contractor on the work, it is well for the
insert a clause in the specifications compelling
prove that he either has or can readily procure the
he possesses ample funds, that either he has had
ence himself, or has arranged to retain as an assist
had such experience, and that his reputation for
estly and faithfully is unquestioned. Before letting
engineer should see whether the successful bidder
ments; and if not, he should assume the respon
bid. In the case of the builder being a private
this difficulty can be avoided by choosing as compet
who fulfil the conditions; but in the case of pub
is allowed to compete, and the low bidders are of
perienced, and without proper plant or sufficient fu
prosecute the construction in the manner desired.

Engineers should assume the responsibility of
at figures either below cost or so small that the
lematical; because, unless a contractor is making
pretty sure to slight it and to cause serious trouble
of this kind by the engineer is often used as a
favoritism, either through friendship or for a
but the dread of such an attack on his character
from doing his duty. In taking a step of this kind
involving himself in a hard fight, hence let him
with all the evidence necessary to ensure his winning

In writing the specifications for a bridge, the
all the responsibilities that are rightly his, and
any of them upon the contractor. He should
convictions, and should prove it by telling in the
thing that he knows concerning the conditions
instead of leaving the contractor to ascertain
It is a cowardly expedient to dodge responsibility
correctness of the data furnished is not guarant
other hand, it is right to point out that the said
plete and that the contractor must provide for

may arise. The author, on more than one occasion, has had clients criticize his specifications because of their being too full and because of his giving the bidders too much information, on the theory that each bidder should examine the ground and get all the needed information for himself. This was suggested for the purpose of avoiding responsibility for the company. The author's answer to any such criticism is that, unless the bidders are furnished with complete information, they will tender high, and the company will spend money unnecessarily in what may after all prove to be an unsuccessful endeavor to dodge responsibility; for in case of litigation the courts generally see that the contractor is given his just due.

No engineer should force a contractor to go into court in order to settle questions and disputes that arise between the company and the contractor. The engineer is the arbiter, and he should not shirk responsibility by refusing to settle disputed points. It is true that, notwithstanding the statement of the specifications to the contrary, he is not necessarily the final arbiter; as the courts have held that any stipulation in a specification which takes away from either party to the contract the right to appeal to the law against the engineer's decision is illegal and therefore void, because it is adverse to public policy, in that its effect is to deprive the courts of their jurisdiction. However, it is found that the courts seldom, if ever, reverse an engineer's decision on a disputed point, unless it be clearly proved that he was actuated by dishonest motives in making it, for both the judge and the jury feel that the engineer knows much more about his own business than they do.

In the event that the lives of the contractor's men are endangered through strikes or threats of any kind, it is the duty of the engineer to see that they are properly protected; and he should not shirk the responsibility of advising his client to call in the aid of government troops whenever he deems such a precaution necessary. When the client's property is endangered in any way, for instance by fire, flood, or mob, the bridge engineer's place is where the danger is greatest; and it is his obligation personally to use every endeavor to save the imperiled possessions, no matter what may be the risk to himself. His duty under these circumstances is analogous to that of an army officer; and he must forget for the time being all personal considerations and devote his entire attention and energy to saving the property confided to his charge. Occasions of this kind are liable to occur in the practice of any bridge engineer, and when they do he must face the danger manfully in order to encourage his workmen and assistants to do their duty. The following little stories will exemplify this statement:

When a certain bridge engineer was a young man, he was in charge, for the contractors, of the construction of a railway bridge across a western river. During the winter falsework had been built across the stream, and in the spring, when the ice went out, large cakes of it lodged against the piles and threatened the work with destruction. The engineer who

[illegible] and [illegible] and commenced operations [illegible] his attempt was successful [illegible], and by their united efforts, [illegible] work was saved. Not a single pile [illegible] left considerably out of line.

On another occasion when repairing a [illegible] badly crippled during a flood, the workmen, [illegible] to fall, left the structure and would not [illegible] bridge engineer led the way, nor would they [illegible] consequently he had to stay until it was made [illegible] by timbering.

CHAPTER LXXVII

ETHICS OF BRIDGE ENGINEERING

Ethics has been well defined as "the science of right conduct, or the body of laws governing the relations between human beings." Although there are a number of elaborate treatises on that subject, there has been no well-considered effort to formulate a working code of ethics for the engineering profession. A few desultory endeavors have been made to codify the laws, but none have been well rounded or successful, consequently the profession has but little in this line to work upon except the "golden rule," which in technical life may be best stated by the expression "endeavor always to do the square deal by everybody."

In this chapter, which is supposed to deal only with the ethics of bridge engineering, but which unavoidably touches upon that of engineering in general, no attempt will be made to formulate a set of rules to govern the actions of bridge engineers or to establish a system of ethics; but the author will merely state in detail his ideas of what the bridge engineer's treatment of others and their treatment of him ought to be, in the hope that his suggestions may prove useful to his professional brethren, and may eventually aid in the establishment of a complete and universally recognized code of ethics for engineers.

Until quite recently, the American Society of Civil Engineers has rather discouraged the inauguration under its auspices of a code of engineering ethics; nevertheless the question of its so doing has come up from time to time, and not very long ago a short and rather incomplete code was adopted. Its restrictions are all covered in the contents of this chapter, which was written as far back as 1907. Any code, to be generally acceptable to the profession and to have any prospect of actual adoption in engineering practice, would have to be essentially different in character from many of those that have been suggested in more or less detail by certain engineers. The engineering profession is not composed of saints nor of mean-spirited hypocrites, who, when struck on one cheek, make a practice of turning the other for another blow, but of courageous, hard-fighting men, who are learning to stand up for their rights, and who will not brook imposition. If the engineering profession were limited to cultured gentlemen, the ideals of these ethical dreamers might be materialized; but, unfortunately, there are all kinds and conditions of engineers (real and so-called), ranging from the broad-gauge consulting engineers and the chief engineers of our principal railways

and manufacturing corporations, trained at college and in the technical schools, to the rodmen or even the roustabouts on surveys; for in this free country of ours any one may call himself a civil engineer, provided he can read and write and has had a little practical experience in a most subordinate capacity on some line of engineering construction. Are these rodmen, roustabouts, highway bridge agents, and others of that ilk to be considered by the engineers at or near the top of the profession as professional brethren and treated with all the courtesy that they would naturally show to their peers? Decidedly not. They should, of course, be treated courteously; but when they have the effrontery, as they sometimes do, to advance their opinions concerning important technical matters in opposition to those of engineers who have an acknowledged right to be considered authorities, they should be relegated to their proper place, even if it require some plain speaking to put them there. Engineers of acknowledged standing should have the privilege of drawing the line somewhere and of saying who are and who are not worthy of being considered in their class. For bridge engineers the best criterion is the question, "Does the man under consideration belong to the national society of civil engineers, and, if so, in what grade?" As every high-class bridge engineer either does or should belong to that society, no hardship will be done if an individual who is not a member thereof in any grade and who poses as an expert bridge engineer when competing for work is refused the consideration due an engineer of generally acknowledged standing.

But some ethical cranks will say, "Engineers ought not to compete for work, for by so doing they will lower the standing of the engineering profession and bring it into disfavor with the public." Such a sentiment as that is mawkish humbug and unworthy the consideration of any live man; for in this rapidly developing country competition in all walks of life is inevitable. If it were suppressed in engineering, the profession would receive a serious backset to its development; because the unscrupulous, the incompetent, and the ignorant practitioners, if sufficiently aggressive (as they certainly are) would secure all the work; and the science of design would soon degenerate into rule-of-thumb practice. It is not unusual in bridge work for the contractor (who often dubs himself an engineer without having any real right whatsoever to that title) to make the claim that he is better posted on bridge designing and construction than the consulting engineer who has made a life study of the subject; and not infrequently he succeeds in impressing this belief on inexperienced and unsophisticated persons who have bridges to build. When a bridge engineer encounters opposition of this kind, he ought to be at liberty to express himself freely concerning the relative standing of true bridge experts and incompetent, ignorant contractors. His doing so is no breach of real engineering ethics.

Again, certain sentimental engineers contend that it is *infra dig.*

for an engineer to patent anything that he discovers or evolves, because it is detrimental to the high standing of the engineering profession and tends to retard progress. Surely "the laborer is worthy of his hire"; and if men in other walks of life have the privilege of patenting their inventions, why should not engineers? To bar them thus would be to put the profession at a disadvantage instead of enhancing its dignity as claimed. Most assuredly, every engineer who evolves anything patentable upon which he can make money by securing exclusive rights to manufacture or use, and who does not avail himself of the privilege which the laws of the country grant, makes a mistake. It is all very well to be generous to one's professional brethren, but it is more important to be just to oneself and to those who are dependent upon one. A great many of our large industries are based upon patents taken out by engineers. Who can imagine the development of the air-brake, the steam turbine, the block-signal systems without the protection and profit afforded by the patent? If the invention must be given to the world without charge, who would spend the years and the fortunes devoted to developing and perfecting machines such as the Curtis turbine? It is a well-defined part of every system of progressive government to protect and encourage the inventor; and in these days the inventor is largely the trained, scientific engineer. If a consensus of opinion among engineers of reputation were taken on this question of patents, the result would certainly be overwhelmingly in favor of the technical man's maintaining his personal rights.

The same sentimental engineers before mentioned contend that one engineer should never criticize another engineer or his work. This is eminently right and proper under some circumstances, but not always. For instance, if a man does something wholly unprofessional or dishonorable, or if his work is of a dangerous character, it would be absurd sentimentality to refrain from criticism merely from notions of ethical propriety—in fact, in some cases it would be most reprehensible.

Again, objections have been raised to an engineer's furnishing information gratis to prospective clients, on the plea that it is ruinous to the profession to do so. This, as a rule, is correct; nevertheless there are occasions when an engineer is able to tie up for himself future engineering work of great magnitude by giving at the outset his services free of charge to the promoters; and he would be foolish if he did not avail himself of such opportunities. At the same time, if he fails to bind the promoters in writing to retain him in case the project materializes, he makes a grave mistake as far as his own interests are concerned, and he does not do his duty by the profession, because he lowers the value of engineering knowledge in the public mind and encourages dishonest practice among promoters at the expense of engineers in general.

Following the lead of other writers on engineering ethics, the author will divide ethics for bridge engineers into the following heads:

[illegible] the duty of the bridge engineer [illegible]

[illegible] the duty of the bridge engineer [illegible]

[illegible] The duty of the bridge engineer to [illegible]

[illegible] of these divisions will be considered [illegible]

THE DUTY OF THE BRIDGE ENGINEER

It is the duty of every bridge engineer at all
advance the interests of the engineering profe
tive method of refraining from all unprofessional
positive one of giving direct aid in many ways.
stant efforts to maintain its dignity, to raise its
ility, and to enlarge its field of usefulness. He
its unwritten but generally accepted rules, should
or censorious comments on the profession as a
members, should adopt every legitimate means
mulated knowledge of the profession, and should
deference to his seniors by recognising readily
have done for the science of engineering. He
est in all that he does, whether it be in paying
subordinates and contractors, preparing specifica
ments, or making scientific technical investigations.
honest, but his life both in public and in private

He should make a practice of giving to his
the benefit of all that he discovers, mainly by the
phlets, and addresses, never entertaining for a m
pseudo-economic notion that what he learns should
own personal benefit only.

He should make a point of seizing every oppo
velop the young engineers with whom he is thrown
them explanations of difficult points, advice, and
asked to do so, he should lecture to engineering
matters that will prove interesting and valuable to
any charge for such services; for it is the bounden
ful engineer to aid the professors of civil engine
students concerning practical matters that are n
books and about which the professors are not so

In addition to leading a moral life, the bridg
minor offences against the proprieties and the
engineers, being specially careful not to adver
It is unnecessary to suggest anything about the

[illegible] and that the perpetrators of the [illegible]
[illegible] While it may seem [illegible] for [illegible]
[illegible] favors as a proffered cigar, it is best to [illegible]
[illegible] captious critics no opportunity to question [illegible]
[illegible] Such fastidiousness, however, may be carried [illegible]
[illegible] once some years ago by a young engineer [illegible]
[illegible] had tried to bribe him by asking him to lunch [illegible]
[illegible] individual can object to the courtesies usual [illegible]
[illegible] between the contractor and the engineer, there [illegible]
[illegible] persons on the lookout to make trouble, hence [illegible]
[illegible] contractor and the engineer to be seen together [illegible]
[illegible] for them to attend to the business which they
[illegible] The author carries this precaution so far as to [illegible]
[illegible] stopping at a contractor's camp for a meal either [illegible]
[illegible] tip the cook or waiter so liberally as not to leave him
[illegible] indebted for the courtesy and convenience afforded; and
[illegible] insisting that none of his field men accept similar
[illegible] the contractors without returning fully the compliment

[illegible] for an engineer, unless he has just cause, to speak slight-
[illegible] opinion of a brother engineer; and he should never
[illegible] the success of others. He should avoid expressing
[illegible] opinions; and, except under unusual circumstances, he
[illegible] technical advice when it is not solicited.

[illegible] some that an engineer should never submit plans
[illegible] in the main, the claim is correct, but there are cases
[illegible] engineer has to meet the persons interested in a bridge
[illegible] materially to show a sketch of the style of structure
[illegible] for the proposed crossing. Under these conditions it
[illegible] for him to prepare and offer such preliminary plans.
[illegible] to convince county commissioners and men of that
[illegible] to retain a specialist to design and supervise the man-
[illegible] of their proposed structure, especially when
[illegible] they prefer the "good, old-fashioned way of let-
[illegible] engineer is sometimes told that they have no
[illegible] whether the work can be done for the amount of his
[illegible] account they are unwilling to bind themselves to
[illegible] fee asked. All that he can then do to secure the en-
[illegible] offer to prepare the preliminary plans and complete
[illegible] the commissioners submit them to bidders for ten-
[illegible] responsible bid is so much in excess of the esti-
[illegible] for their means, the commissioners may reject
[illegible] anything for their preparation. Any bridge

engineer who has the
should not be debarred from doing
its interests.

Sometimes engineers are requested to
except in the type of case just referred to, it
only because of its lowering the dignity of the
cause it is a very risky thing to do. After all
the expense incidental to the preparation of pla
and supervision of at least a portion of the constr
assumed prove to be inadequate and the cost of
tially increased, it would be rather severe pun
able miscalculation of cost if he were deprived of
his fee, especially if, according to contract, he were
tuality to finish the work of supervision.

Sometimes an engineer is asked to give a
a movable bridge of his designing will work prop
demand should be a refusal, unless the proposed
which he controls the patents and claims a royalty
ing of such a guarantee is a risky thing to do, be
no control over the manufacture of the machinery

Bridge engineers should not enter into compet
to the extent of cutting rates, as such action lowers
eyes of the public, besides tending to keep down
engineers in general. It is far better to tender
for the work upon the basis of professional standing
and reputation for finishing one's bridges satisfactor

Bridge engineers should avoid connecting the
any scheme or project that is merely of a specula
is chimerical, or that is not backed by real merit
offered a retainer to do some work on such a p
its value, it is not necessary for him to refuse the
tached, unless he can see that the promoters simpl
tablished reputation as an endorsement of their ent
is willing or not to work on a project of doubtful
matter to be solved by personal considerations of
than it is a question of engineering ethics; never
who claim that the acceptance of a retainer on su
tion of the unwritten code. Again, one must not
ect must have a beginning and that many which
at first are ultimately successful; while, on the other
which at the outset appear most roseate prove ev

In regard to the ethics involved in the giving
many engineers disagree. Some say that no exp
the pay of either contestant, but should receive
This method would be ideal; but the established

would have to be overturned before such a radical change could be effected. It seems a shame that such should be the case, because the sight of a number of engineers of good standing all testifying in a legal controversy in the most partisan manner and pledging their reputations as to the correctness of diametrically opposed statements. is not very edifying, nor is it conducive to elevating the engineering profession in the esteem of the public. The author makes it his policy to refuse, whenever possible, to give expert evidence; and when he cannot avoid it, he explains in advance to the client that he will tell exactly what he knows or ascertains by investigation, no matter who will be benefited or injured by his testimony—in fact, that he will not be partisan under any consideration. It is hardly necessary to say that he is not very often sought after as an expert witness. Bridge engineers in general might do well to take the same stand on this point, for the reasons that the rôle of expert witness is a difficult one to fill satisfactorily, that it is nearly always attended by considerable grief, that the compensation it brings is too small, and that one makes through it more enemies than friends. As a compromise, one might arrange for a certain fee, fixed in advance, to investigate and report upon the case at issue; then, if the result be unfavorable, drop it permanently, but otherwise (for an additional fee) continue it and give evidence, the decision concerning continuance. however, being left entirely to the engineer.

The bridge engineer should confine himself to either purely professional work or contracting. He should never attempt to do both, although it would be perfectly proper for him to change from one line to the other. This is a case of where "no man can serve two masters." If he is a professional bridge engineer, he will require all work to be done in the best practicable manner consistent with reasonable expense, while if he is a contracting engineer, his object will be to have it done as inexpensively as possible. These two points of view are irreconcilable. It is true that with very broad-gauge men they approach each other more or less closely, but they will never meet; hence, if an engineer is to be thoroughly consistent, he should remain on one or the other side of the fence, and should, under no circumstances, attempt to straddle it. If an engineer is in the bridge-contracting line and at the same time makes plans, specifications, and estimates for clients, he will antagonize the regular consulting engineers, which, to say the least, is bad policy; and if he is a consulting bridge engineer, he will give deep offence to bridge builders, if he ever takes a contract for construction. Moreover, no engineer who attempts both consulting practice and contracting simultaneously will ever be able to secure public confidence to anything like the extent which he would were he to confine his attention to purely professional work.

Once in a while a bridge engineer is asked to give a personal bond guaranteeing his faithfulness and integrity; but it is invariably refused. Such a request is an insult to the engineering profession. No lawyer,

[illegible] the [illegible] of civil [illegible] are sometimes [illegible] structures. They should [illegible] compensation for the time and expense [illegible] the engineering of the structure [illegible] competition, and unless the judges who [illegible] competent and honorable men. Otherwise, the [illegible] is almost certain to be loss of time, money, [illegible] and probably all, of the competitors, as well as [illegible] work and injury to the profession. The [illegible] with authority, for in times past he [illegible] and although apparently successful, he failed to [illegible] money to cover expenses.

There appears to be some uncertainty in the [illegible] general about the propriety of one's utilising in [illegible] professional degrees that he has received. There [illegible] tion raised to his using them on his professional [illegible] England, where engineers are prone to look [illegible] method of professional advertising. Beyond this [illegible] believe in going; for he would not advise employing [illegible] respondence or in making reports, as the term "Civil [illegible] sulting Engineer" after the signature should suffice [illegible] title-page of a technical book, an engineer-author [illegible] stating all the distinctions that he has ever earned.

THE RELATION OF THE BRIDGE ENGINEER TO HIS [illegible] BRETHREN

The question of who are to be considered as the [illegible] fessional brethren has been treated in this chapter [illegible] restrictions indicated it is not very difficult to [illegible] of conduct that should guide a bridge engineer in [illegible] fellows and with those outside of the pale. When [illegible] with quacks and charlatans, he should not hesitate [illegible] posing them in as public a manner as possible, [illegible] consult with them or to have anything to do with [illegible] They are not worthy of consideration, for to their [illegible] tion, and dishonesty are due the failure of many [illegible] the destruction of bridges that in the aggregate [illegible] money. The blame for these failures and dis[illegible]

[illegible]
[illegible] He should be as careful of [illegible]
[illegible] as he is of his own. When [illegible]
[illegible] of another engineer he should refuse to [illegible]
[illegible] agreed to accept him; and if he finds anything [illegible]
[illegible] construction of which he does not approve, he should [illegible]
[illegible] other engineer so as to give him an opportunity [illegible]
[illegible] designing or building in the manner criticised [illegible]
[illegible] the work, the consulting engineer should deal as gently [illegible]
[illegible] brother engineer's faults, and should take pains to
[illegible] the various good points in the design and construction.
[illegible] report full and thorough in every particular, omitting
[illegible] and stating clearly his objections to every feature
[illegible] approve, he should be careful to humiliate his brother
[illegible] possible.

[illegible] saying that one should never try to undermine another
[illegible] his position. Such an action would be preju-
[illegible] reputation of the engineering profession, besides being
[illegible] improper.

[illegible] should attempt to take away the employees of a
[illegible] but, should any of them apply to him for work,
[illegible] such application he should consult with their employer
[illegible] is perfectly agreeable to him to let them go.

[illegible] should give an endorsement to an assistant unless
[illegible] of it, no matter what the temptation to do so may
[illegible] improper endorsement would deceive his brother
[illegible] would tend to lower the status of the profession.

[illegible] should consider accepting a position already held
[illegible] unless that engineer's resignation or dismissal has
[illegible]ed.

[illegible] although not obligatory, that bridge engineers should
[illegible] to their own line of work and not cut into those
[illegible] they are likely to keep more popular profession-
[illegible] if they made a practice of wandering into neigh-
[illegible] It is no crime, though, for a specialist to
[illegible] line of work in his practice, especially if he has
[illegible] who are versed in other lines than his.

[illegible] engineer encounters in his practice features of
[illegible] which he is not familiar and which are outside
[illegible] call in to his assistance the best engineering
[illegible] practicable, he should make his client pay for such
[illegible] he should pay for them himself. The expert

thus called in, before sending his bill, should ascertain who is to pay it; and, if it be his brother engineer, he should make it as small as he conscientiously can. He ought not to be expected in such a case to work for nothing; but he should not charge for any advice of a general nature which he can give his brother engineer without expense to himself. One should be very chary, however, of asking for assistance for which he cannot pay, as so doing tends toward imposition on good nature.

Ingratitude and forgetfulness of past favors are an indication of an unworthy nature, and as such are a violation of the ethics of engineering. Instances of these objectionable traits are, fortunately, rather rare, although not entirely unknown in the engineering profession.

THE DUTY OF THE BRIDGE ENGINEER TO HIS CLIENTS OR EMPLOYERS

When a bridge engineer is retained on any work, it is his duty to devote his energies loyally and conscientiously to the interests of his client. Nothing should be allowed to stand in the way of his duty, unless the demands of the client conflict with the engineer's sense of what is right and just. In such a case he should argue the matter with his employer until one or the other is convinced; and if an agreement cannot be reached, the engineer should tender his resignation, for he cannot afford to have his name connected in any way, either directly or indirectly, with anything savoring of fraud or injustice. Usually, when an engineer takes such a firm stand as this, the client will give in and will be persuaded to do what is right. Engineers are sometimes asked to falsify reports and estimates or to give false evidence on the witness stand; but a firm negative to the request will generally effect its withdrawal. If it does not, there is only one thing for the engineer to do, no matter what the cost to himself may be.

A bridge engineer should always insist that the amount of his fee for any work be fixed in advance of his undertaking it. If he is careless enough to fail to do so, he may have either to permit the client to determine the amount or to resort to the courts for collection.

Within the limits set by the demands of honesty and integrity, an engineer cannot be too loyal or too devoted to the interests of his client. He should fight for his client's rights as he would for his own, and should aid him with advice whenever opportunity offers, even if such advice is not solicited. Whenever he sees that his client is about to make a mistake of any kind, he should warn him and should use every possible means to convince him of his error.

Unless it is otherwise agreed upon, the bridge engineer who prepares plans has a right to keep the tracings; but the client is entitled at any time to as many blue-print copies thereof as he may desire, provided he pays the actual cost of making them. Nor has the client a right to build

more than a single structure from a set of plans or permit any one else to do so without giving the engineer additional compensation, unless, perchance, the contract between the parties was so drawn.

A bridge engineer need not consider that his entire time and attention should be given to the work of one client, unless a special agreement was made to that effect; for he should be at liberty to do all the other work he desires, provided that he does not in any way neglect his client's interests.

A bridge engineer should not permit his clients to give directions to any of his employees, as all instructions should be delivered to him directly. This is necessary, not only to ensure the work being done properly, but also to maintain discipline in the engineering force.

It is the duty of every bridge engineer, when preparing specifications for submission to bidders, to furnish them as full data as possible, in order that his client may obtain the lowest possible tenders consistent with the securing of proper construction. This matter is treated at length in another chapter.

A bridge engineer must not take that method of settling difficulties which is easiest for himself, but the one which is best for his client's interests.

If a client has any matter that rightfully he deems should be kept secret, his engineer should not only refrain from speaking of it to any one himself, but he should also prevent all his employees from so doing —if necessary, by threat of dismissal.

In all cases reports should be made with perfect frankness, even though they be displeasing to the client.

The study of true economy in designing and construction, or, in other words, the avoidance of all extravagance, is an important duty of a bridge engineer to his client even if his own personal labor is materially augmented thereby.

No true bridge engineer will ever be persuaded either by contractors or clients to call for bids on a structure upon the basis of the bidders submitting competitive plans, for not only does this method involve an acknowledgment of his technical inferiority to those thus invited to tender, but also it results in procuring for his clients designs which are greatly inferior to the best possible that can be evolved.

THE DUTY OF THE BRIDGE ENGINEER TO HIS EMPLOYEES AND THEIRS TO HIM

The bridge engineer's duty toward his employees consists mainly in seeing that they are sufficiently compensated for their services, whether they be paid by him or by his clients, that they are invariably treated kindly and courteously, that they are allowed every opportunity to obtain valuable experience, that a personal interest is taken in their welfare and professional advancement, that they are given full credit for all

original or special work which they do, and that when they leave they receive (if they are worthy) good recommendations to aid them in securing other positions. The bridge engineer should encourage his subordinates to join the leading engineering societies, and should direct their technical reading and advise them concerning professional matters, to the end that they may develop to the utmost the best that is in them and make themselves worthy members of the engineering profession.

When issuing orders, the bridge engineer should give them to the engineer in charge and not directly to the draftsmen or underlings; because if he does deal directly with such subordinates, he upsets the routine of the work and breaks up the discipline of his organization. There are times, though, when it is necessary to depart from the observance of this rule, such, for instance, as when the engineer in charge is absent; and then the latter as soon as possible should be told courteously of the direct instructions and the reason why they were so given.

The duty of the employee to the bridge engineer consists mainly in doing his work thoroughly and to the best of his ability, working full time always and overtime when it appears necessary, studying how best to make himself useful to his employer, and acting loyally to him at all times in both word and deed. No subordinate has a right to work during his spare time for other parties in order to increase his income, because all his energies belong to his employer. If he does work thus at night and on Sundays, he will be so tired during office hours that he will not be able to attend properly to his regular duties, and, consequently, his employer will be defrauded. Moreover, his doing such outside work is generally in direct competition with his employer, as it would naturally be brought to the office were it not that the one who wants it done thinks he can obtain it more cheaply from the employee than from the employee's principal. It would be bad policy for a bridge engineer to retain in his service any employee who does outside work in this way.

THE DUTY OF THE BRIDGE ENGINEER TO HIS CONTRACTORS

The treatment of his contractors by a bridge engineer should be courteous but firm, kindly but with dignity, liberally but with strict justice both to them and his clients. He should do all that he can to aid the contractors to finish their work expeditiously and economically, so that they will make a fair profit, providing his principals secure satisfactory construction. He should brook no interference or dictation from contractors, yet should always listen to any of their suggestions when politely made, and should act thereon if, in his opinion, to do so would be good policy. If he can legitimately grant them small favors in respect to payments on account, he should so oblige them, provided that he sees they are in pecuniary difficulties, and provided that he in no way jeopardizes his client's money. In short, he should be their true friend in

laying himself open to any with all disputed points between his engineer should not forget that he is not as a partisan.

the Bridge Engineer to the Public

neglect their public duties, probably for the reason always extremely busy, but possibly because they are so in their professional work that they hate to spend else. They should, however, devote at least as political and social matters as good citizens who usually do—possibly more, for an engineer is in position to give sound, valuable advice public policy, and his broad and liberal education an interesting member of the social world. It would him to hold public office, for he has not the time to he should be willing to act as adviser on matters of engineers were to make a point of doing so, the effect be to cause the profession to be better known and more by the public.

of the Bridge Engineer to Himself

his duties to everybody else, the bridge engineer has which he should not neglect. He owes it to himself to legitimate opportunities for professional and pecu- his professional character from all assaults, to main- strict honesty and for the prompt payment of all all who know him recognize that his word is as good a promise once given by him is certain to be fulfilled, as a man of science through his technical investi- practicable, also through suitable recognition of his worth and other honors, and to broaden his general so as to make himself what is popularly man."

chapter the author desires to repeat the hope that when the engineering profession will possess a complete code of ethics; but he recognizes that it difficult to enforce the regulations of such a code for violations thereof, except in the extreme case when it would be practicable to punish the guilty all the technical societies of which he may be

CHAPTER LXXVIII

GENERAL SPECIFICATIONS GOVERNING THE DESIGNING OF THE SUPERSTRUCTURES OF STEEL BRIDGES, TRESTLES, VIADUCTS. AND ELEVATED RAILROADS*

CLASSIFICATION

1. *Classification of Bridges in General*

As regards these specifications, all structures are divided into two general classes, viz., railroad bridges and highway bridges. The designing of these classes will differ mainly in the loadings and in certain limitations of sizes of parts; and although the specifications are written so as to cover both classes, no trouble whatsoever should be experienced by the designer in applying them to any particular class or to any type of structure. Electric railway bridges shall conform to the specifications for highway bridges, except as otherwise provided.

2. *Classification for Highway Bridges*

Highway bridges shall be divided into three classes, viz., Class A, which includes those that are subject to the *continued* application of heavy loads; Class B, which includes those that are subject to the *occasional* application of heavy loads; and Class C, which includes those for ordinary, light traffic. In general, it may be stated that bridges of Class A are for densely populated cities, those of Class B for smaller cities and manufacturing districts, and those of Class C for country roads.

MATERIALS

3. *Metal Portions*

In steel superstructures all the parts besides the ties, foot-planks, and guard-timbers of railway bridges and the flooring, pavement, and footwalk slabs of highway bridges shall be of either medium carbon steel or nickel steel, excepting only that bolts and adjustable members are to be of soft carbon steel and rivets of either soft carbon steel or low nickel steel, and that cast iron may be used for purely ornamental work, lamp-posts, large base plates, and a few minor parts of operating machinery for movable spans.

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* Appended to this chapter is a clause index for the use of those who desire to design bridges according to these specifications.

4. *Timber Portions*

Cross-ties, foot-planks, and guard-timbers of railway bridges, and joists, planks, guard-rails, and paving blocks of highway bridges, also all other timber portions of all bridges, shall be of long-leaf, Southern yellow pine, Douglas fir, Pacific Coast cedar, or other timber which, in the opinion of the Engineers, is equally good and serviceable.

RAILWAY BRIDGE FLOORS

5. *Timber Floors*

In railroad bridges the wooden floor shall be so designed as to ensure safety from passing trains for the railroad employees, refuge bays three (3) feet by three (3) feet outside of clearance being provided every one hundred (100) feet for deck spans. The spaces between the ties shall not, in general, be less than five (5) inches nor more than six (6) inches wide. The sizes of the ties shall be such as to give the requisite resistance to bending, under the assumption that the load on one pair of wheels is distributed equally over three ties, the effect of impact being considered.

All ties shall be proportioned by the formula,

$$M = \frac{1}{6} Rbd^2,$$

where M is the greatest bending moment in inch-pounds upon a tie, R is the intensity of working stress in pounds per square inch, b the width of the tie in inches, and d the depth of same in inches.

The net dimensions of timber shall invariably be employed when using the preceding formula.

No tie shall be less than seven (7) or, preferably, eight (8) inches wide, nor less than eight (8) inches deep, nor less than ten (10) feet long, except in the case of elevated railroads, where the length may be reduced to eight (8) feet and the depth to six (6) inches for a spacing of five (5) feet between central planes of longitudinal girders.

Ties shall be dapped to a full and even bearing not less than one-half (½) inch on to the stringers; and each alternate tie shall be secured thereto at each end by a three-quarter (¾) inch hook bolt, having at the hook end a square shank at least two (2) inches long to prevent the bolt from turning.

All timber bolts shall be of soft steel.

Outer guard-timbers shall be 6″ × 8″ laid on flat, dapped one (1) inch on to the ties, and placed so that their inner faces shall be not less than twelve (12) inches nor more than fifteen (15) inches from the gauge-planes of rails.

Where inner guard-timbers are employed, they shall be 6″ × 8″ on flat, dapped one (1) inch on to the ties, and placed so that their outer

[illegible]

[illegible]. Each guard-timber must be [illegible] joint of at least six (6) inches' lap, quarter (¾) inch bolt. Lag-screws may be the written permission of the Engineer.

Guard-rails shall extend over all piers

Steel tie-plates shall be used between all shall be attached to the ties by special screw Engineers shall direct otherwise in writing.

6. *Ballasted Floors*

A buckled-plate floor with ties in ballast wooden floor, in which case the size of the 8″ × 8′. All buckled-plate floors must be to retain water, and the upper surface of the tected from rusting by a liberal use of the best coating. A solid timber floor supporting ballast adopted, in which case the timbers are to be and the entire live load, impact load, and assumed to be uniformly distributed over the is covered by the ballast. Or a reinforced sides to retain the ballast may be employed.

7. *Trough Floors*

A steel trough floor having a wooden tie or without ballast, may be substituted for the

8. *Floors on Skew Bridges*

The ends of deck plate-girders and track bridges at abutments shall be square to the track be used.

HIGHWAY BRIDGE FLOORS

9. *Timber Floors*

In highway bridges the sizes of the timber give the requisite resistance to bending, the sidered; but no joist shall be less than three (12) inches deep.

As a rule, the depth of a joist shall not exceed four (4) times its width. Otherwise, the joists shall be properly bridged at distances not exceeding eight (8) feet.

They shall be proportioned by the formula given previously for ties.

Joists shall be dapped at least one-half (½) inch upon their bearings, and shall have their tops brought to exact level before the planks are laid thereon.

They shall be spaced not to exceed two (2) feet between centres, shall, preferably, lap by each other so as to extend over the full width of the floor-beam, and shall be separated half an inch, so as to permit the circulation of air. The outside joists, however, shall abut so as to provide flush surfaces from end to end of span.

When steel joists are used, wooden shims, at least four (4) inches deep by six (6) inches wide, shall be effectively bolted to their top flanges through holes therein, or else secured thereto by approved metal clips.

Floor planks for the main roadway shall be at least three (3) inches thick and from eight (8) to ten (10) inches wide, and shall be laid, either transversely or diagonally but never longitudinally, with one-quarter (¼) inch openings. Each plank shall be spiked to each joist on which it rests by two (2) seven (7) inch cut spikes, the holes for which shall be bored in order to avoid splitting the timber, or else by two (2) seven (7) inch wire nails.

Whenever a wearing-floor is used, the lower planks must be planed on the upper side and sized to a uniform thickness, and the wearing-floor must be planed on the lower side so as to ensure a perfect bearing between the upper and the lower layers. The planks of the wearing-floor shall be laid either transversely or diagonally but never longitudinally; and those in the lower floor must always be laid in some other direction than that of the planks of the upper floor.

Floor planks for footwalks shall be at least two (2) inches thick and not much more nor less than six (6) inches wide, and shall be laid with one-half (½) inch openings. Each of the said planks shall be spiked to each joist upon which it rests by two (2) six (6) inch cut spikes, the holes for same being bored, or by two (2) six (6) inch wire nails. The floors of footwalks shall extend to and connect with the floor of the main roadway so as to leave no open spaces anywhere in the bridge floor.

All planks shall be laid with the heart side down.

There shall be a wheel-guard of a scantling not less than four (4) inches by six (6) inches on each side of the roadway to prevent wheel hubs from striking the trusses. It is to be laid on its flat, and blocked up from the floor by shims at least one (1) foot long, six (6) inches wide, and two (2) inches thick, spaced not more than five (5) feet between centres, each shim being spiked to the floor by four (4) four and a half (4½) inch cut spikes. The guard-rails are to be bolted to the floor through the centre of each shim by a three-quarter (¾) inch bolt, which must

[illegible] through the joist, beneath [illegible] the wooden hand-rail posts, the [illegible] guard-rail, so as to make a flush [illegible] The joints in the guard-rail are to be [illegible] long, each located symmetrically over the [illegible] bridge is on a heavy grade, the inner, upper [illegible] to be covered with steel angles fastened to the [illegible] screws, spaced about eighteen (18) inches [illegible] guard-rails from the injurious effects of [illegible] brakes for heavily loaded wagons.

When wooden hand-rails are employed, they [illegible] proved timber, the posts being 4″ × 6″ × [illegible] of 2″ × 6″ timbers (one on its flat and the other [illegible] the first for a hand-rail), one (1) run of 2″ × 12″ [illegible] cases a run of 2″ × 6″ plank near the floor. The [illegible] not to exceed ten (10) or, preferably, eight (8) [illegible] railing is to be firmly attached to the bridge and [illegible] the rigidity of a hand-railing is dependent upon the [illegible] the latter must be properly bridged and stiffened [illegible] hand-railing of equal strength and rigidity, and [illegible] the Engineers, will, however, be accepted.

When iron hand-railing is employed, it is to be [illegible] pattern, pleasing to the eye, and rigidly attached [illegible] beams. Both through and deck bridges are to be [illegible] rail on each side, not less than three and a half [illegible] the floor. In case there be any liability of a [illegible] railing, its height must be increased to four and a [illegible] feet. There must be a hand-rail on the outside of [illegible] than three and a half (3½) feet in height above the [illegible]

All floor-timbers, guards, and railings shall [illegible] abutments and make suitable connection with the [illegible] ends of the structure. Aprons or cover-joints of [illegible] vided at the ends of spans, if required.

10. *Street-Railroad Track*

Should there be one or more street-railroad [illegible] there should generally be placed directly under [illegible] properly proportioned to resist the effect of the [illegible] the rail. The rails shall be so laid as to offer as little [illegible] to the wheels of vehicles.

11. *Paved Floors*

Where paved floors are adopted, the pave[illegible] kind, and shall be built according to the lat[illegible]

fications. Paved floors are always to be supported by a reinforced concrete base resting on steel stringers, preferably of rolled I-beams, spaced generally not to exceed five (5) feet between centres. The surface of the pavement must be thoroughly drained so as not to retain water.

12. *Superelevation on Curves*

On curves the outer rail must be elevated the proper amount for the degree of curvature and for the assumed medium velocity of trains; and this elevation must be framed into the ties, or else be provided by raising the outer stringer or girder, and depressing the inner one, if necessary. The formula to be used for total superelevation on standard-gauge roads is

$$E = \frac{4V^2}{R};$$

where E is the total superelevation in inches of the exterior rail above the interior rail, V is the assumed medium velocity of train in miles per hour, and R is the radius of the curve in feet.

The assumed medium velocity of the train in miles per hour shall be taken at

$$V = 42 - 1.75D;$$

where V = speed in miles per hour,
and D = degree of curvature.

The total superelevation is to be obtained by elevating the outer rail and keeping the inner rail at grade. The run-ups on the tangents at ends of curves are to be not less than forty (40) feet long for each inch of superelevation.

In Fig. 8*a* are given the superelevations required for curves up to twenty (20) degrees.

13. *Rerailing Apparatus*

Unless the Engineers give written permission to the contrary, at each end of every bridge or trestle there is to be placed a rerailing apparatus that will, in the most effective manner practicable, return to the track any derailed car or locomotive that is not more than half the width of track gauge out of line.

14. *Spacing of Stringers and Girders in Railway Bridges*

In general, stringers for through-bridges shall be spaced from seven (7) to eight (8) feet centres for single-track bridges and from six (6) feet six (6) inches to seven (7) feet for double-track bridges and half-through plate-girder bridges. In elevated railroads the spacing of the longitudinal girders may be made as small as five (5) feet centres. Single-track, deck plate-girders may be spaced from seven (7) feet to ten (10) feet centres,

[illegible]

[illegible]. The spacing of [illegible] in the clearance requirements [illegible]

When there are four (4) lines of I-beams [illegible] systems of other spans, the beams [illegible] symmetrically about the centre line of [illegible] fifteen (15) inches from centre to centre.

15. *Spacing of Trusses in*

From centre to centre of through trusses [illegible] shall not be less than seventeen (17) feet, or [illegible] span length.

From centre to centre of deck pin-connected [illegible] trusses the said perpendicular distance shall [illegible] in the following table, except in the case [illegible] open-webbed, riveted girders are adopted, in [illegible] spaced according to the directions given for [illegible]

TABLE

SPACING OF TRUSSES IN RAILWAY

Span Length, in Feet
150
200
300
400
500
600 and over

16. *Clearances for Railway*

In single-track, steam-railway bridges the [illegible] shall not be less than that shown in Fig. 22i. [illegible] for double-track bridges also by increasing the [illegible] 28 feet, when the distance from centre to centre [illegible] feet, or to correspondingly greater widths for [illegible]

On curved track, the horizontal distance [illegible] clearance line shall be increased thus:

Single-track through bridges on curves [illegible] trusses or girders and the width between [illegible] Figs. 8e and 8f. In these diagrams,

W = the lateral clearance from the centre line of track required for tangent alignment.

M = the middle ordinate of the curve for a chord equal to the span length.

X = an addition for the overhang of a car 85 feet long and 60 feet from centre to centre of trucks, to be taken as 1 inch for each degree of curve.

Y = an addition in inches (on the inside of the curve only) on account of the superelevation of the outer rail, to be taken as follows:

$$Y = \frac{sh}{5}, \text{ but not more than } 3s,$$

where s = superelevation in inches,

and h = height of top of car above base of rail in feet.

For double-track bridges the increase between clearance lines shall be effected as just explained for the case of structures on tangent.

17. *Clearances for Highway Bridges*

The smallest allowable clear roadway shall be twenty (20) feet, measured between curb lines, with ten (10) feet extra for each additional line of traffic, excepting for cheap county bridges, where it may be reduced to eighteen (18) feet, or even to fourteen (14) feet when the bridge is so short that no provision need be made for teams passing thereon.

The smallest allowable clear headway shall be sixteen (16) feet, except for bridges in cities where the ordinances require a greater height, or for bridges carrying electric railway tracks, in which structures the vertical clearance should be, preferably, twenty (20) feet. The corner-brackets may, however, encroach on the specified clear headway, provided they do not extend either laterally or downward more than five (5) feet.

18. *Spacing of Tracks*

Steam railway tracks shall usually be spaced thirteen (13) feet from centre to centre and electric railway tracks ten (10) feet or more from centre to centre, with a proper increase for sharp curvature.

19. *Effective Lengths*

For pin-connected or riveted trusses the effective length shall be the distance between centres of end-pins.

For plate or open-webbed riveted girders it shall be either the distance between centres of bearing-plates or that between centres of pedestal pins.

For stringers it shall be the distance between centres of cross-girder webs.

For cross-girders it shall be the perpendicular distance between central planes of trusses or girders.

For columns and posts it shall be the [illegible] of axis that are rigidly held in the direction [illegible] considered.

20. *Effective Depths*

Effective depths shall be as follows:

For both pin-connected and riveted trusses, the [illegible] between gravity lines of chords (which must [illegible]

For plate-girders and open-webbed riveted [illegible] distance between centre lines of gravity of upper [illegible] never greater than the distance out to out of flange [illegible]

21. *Styles of Railway Bridges for Various*

For spans under twenty-five (25) or thirty [illegible]

For spans between twenty-five (25) or thirty [illegible] and ten (110) feet, plate-girders.

For spans between one hundred and ten (110) [illegible] and fifty (350) feet, riveted trusses of single [illegible]

For spans exceeding three hundred and fifty [illegible] or riveted trusses with subdivided panels.

The use of pony-truss bridges of any kind is [illegible] only half-through, plate-girder spans, in which [illegible] rigidly in place by brackets riveted to cross-girders [illegible] to exceed twelve (12) times the width of the top [illegible]

In general, double-track truss-bridges shall have [illegible] order to avoid spreading the tracks.

22. *Styles of Highway Bridges for Various*

In general, spans of and below twenty (20) feet [illegible] beams or simply wooden joists; spans from twenty [illegible] feet of rolled beams; spans from thirty (30) to [illegible] girders; spans from sixty (60) to one hundred (100) [illegible] or open-webbed riveted girders of single [illegible] hundred (100) to three hundred (300) feet of riveted [illegible] exceeding three hundred (300) feet of pin-connected [illegible]

The use of pony-truss bridges of any kind is [illegible] only half-through, plate-girder spans, in which [illegible] rigidly in place by brackets riveted to cross-girders [illegible] erally not to exceed twelve (12) times the width [illegible]

23. *Forms of Trusses for Railway*

The forms of trusses to be used are as follows:

For deck-spans having top chords support[illegible]

ren or the Triangular truss with verticals dividing the panels of the top chords.

For other deck-spans and through spans, up to three hundred (300) feet, the Pratt truss.

For spans exceeding three hundred (300) feet, the Petit truss.

For through spans up to about two hundred (200) feet parallel chords are to be employed; but for longer spans the top chords are generally to be made polygonal.

It is understood that these limiting lengths are not fixed absolutely, as the best limits will vary somewhat with the number of tracks and the weight of trains.

24. *Forms of Trusses for Highway Bridges*

The forms of trusses to be used are as follows:

For open-webbed, riveted girders the Pratt truss, or the Warren or the Triangular truss with verticals dividing the panels, the latter being employed for deck spans carrying joists resting on the top chords.

For riveted spans up to about two hundred and fifty (250) feet, Pratt trusses with top chords either straight or polygonal.

For spans exceeding two hundred and fifty (250) feet, Petit trusses.

It is understood that these limiting lengths are not fixed absolutely, as the best limits will vary somewhat with the width of bridge and the live load to be carried.

25. *Main Members of Railway Truss-Bridges*

All spans of every kind shall have end as well as intermediate floorbeams, riveted rigidly to the trusses or girders, for supporting the stringers. The latter are to be riveted to the webs of the cross-girders, and shelf angles shall be provided to support them during erection; but the rivets attaching the said angles are not to be counted upon to carry the stringer or its load. In general, all trusses shall have main end posts inclined. All trusses shall be so designed as to admit of accurate calculation of all stresses, excepting only such unimportant cases of ambiguity as that involved by using two stiff diagonals in a middle panel. Counterbracing shall be effected by using stiff diagonals, as no adjustable truss members will be permitted.

All lateral bracing and other sway-bracing shall, preferably, be rigid both above and below, *i.e.*, the sections must be capable of resisting compression, adjustable rods for such bracing not being allowed under any circumstances. The stiff diagonals of lateral systems in the plane of the loaded chords, which systems are generally to be of double cancellation, shall be riveted rigidly to each other where they intersect and, if practicable, to the stringers where they cross them, and shall be braced apart so as to transfer in an effective manner the thrust of braked trains

[illegible] of the [illegible]

[illegible] shall have [illegible] designed to resist the greatest wind stresses [illegible] flanges of the inclined end posts. The [illegible] as deep as the specified clear headroom [illegible] the trusses is great enough to permit it, [illegible] point a rigid bracing frame riveted to the [illegible] posts, and carried down to the clearance line; [illegible] not great enough for this detail, corner [illegible] and rigidity are to be riveted between the posts [illegible] struts.

Deck-bridges shall have stiff diagonal braces [illegible] posts, figured to carry across safely a shear equal [illegible] truss live load with its impact allowance; and [illegible] between the vertical or inclined posts at each [illegible] strong to transmit properly to the masonry one-half [illegible] (and centrifugal load, if there be any) which is carried [illegible] lateral system of the span.

In pin-connected structures the suspenders, the [illegible] or more panel lengths of bottom chord at each end [illegible] be made rigid members.

All floor-beams in truss spans are to be riveted [illegible] built hangers.

26. *Main Members of Highway* [illegible]

All spans of every kind shall have end as well as [illegible] beams, riveted rigidly to the trusses or girders, for [illegible] or stringers. Steel stringers are, preferably, to be [illegible] of the cross-girders, but wooden joists are generally [illegible] latter. In general, all trusses shall have main [illegible] trusses shall be so designed as to admit of accurate [illegible] stresses, excepting only such unimportant cases of [illegible] when two stiff diagonals are used in a middle panel [illegible]

In the trusses of important bridges counterbracing [illegible] effected by using stiff diagonals, but in cheap [illegible] by employing counters of adjustable rods.

In important bridges with steel stringers, all [illegible] sway-bracing shall, preferably, be rigid above and [illegible] tions should be capable of resisting compression, [illegible] bracing being allowed only in towers of draw [illegible] lateral systems of deck bridges; but in cheap [illegible] and other sway diagonals may be adjustable [illegible] of lateral systems in the plane of the loaded [illegible] generally to be of double cancellation, shall [illegible]

other where they intersect and, if practicable, to all the steel stringers where they cross them.

All through-spans shall have portal bracing at each end, properly designed to resist the greatest wind stresses, and carried as low as the specified clear headroom will allow. The portal struts and diagonals shall be riveted rigidly to both flanges of the inclined end posts. When the height of the trusses is great enough to permit it, transverse, vertical sway-bracing shall be employed at each panel point; otherwise, corner brackets of proper size, strength, and rigidity are to be riveted between the posts and the upper lateral struts.

Deck-bridges shall have sway-diagonals between opposite vertical posts of sufficient strength to carry one-half of a panel truss live load with its impact allowance; and the transverse bracing between the vertical or inclined posts at each end of span shall be sufficiently strong to transmit properly to the masonry one-half of the total wind-pressure (and the centrifugal load for spans with electric-railway tracks on curve) carried by the upper lateral system of the span.

In important, pin-connected bridges, the suspenders, the hip verticals, and two or more panel lengths of bottom chord at each end of span shall be made rigid members.

All floor-beams are to be riveted to the truss-posts in truss-spans, excepting in the case that eye-bars be used for suspenders or hip verticals. In such cases floor-beam hangers may be used, provided they be made of plates or shapes and that they be stayed at their upper ends against all possibility of rotation.

27. *Continuous Spans*

Except in the case of swing-bridges or cantilevers, consecutive spans are not to be made continuous over the points of support.

28. *Railway Trestles*

As a general rule, each trestle-bent shall be composed of two columns battered from one and a half (1½) to two and a half (2½) inches or more to the foot, the bents being united in pairs to form towers. Each tower thus formed shall be thoroughly sway-braced with struts on all four faces, and shall have four (4) horizontal struts at the base and four (4) more in each horizontal division plane of the tower bracing. In trestles of moderate height it is permissible to adopt from one (1) to three (3) or even four (4) solitary bents between the braced towers, which bents may or may not have rocker ends.

The feet of the columns must be attached to anchorages capable of resisting twice the greatest possible uplifting; and the details of the metalwork connecting the anchor-rods to the columns must be such as to make the metalwork and pedestals act as a single piece, so that, if

liable to destruction by overturning, the
of the base. While it is desirable to have
tension from coming on the anchor-bolts, it
count to make the batter of the columns
high trestles. When trestle-bents become unduly
is to be placed midway between the legs so as to
sway-bracing. Care must be taken to provide
and contraction at column feet both transversely

In elevated railroads and trestles of small
placed at about every fourth span or, say, every
feet, or can be dispensed with altogether, when the
by strengthening the columns properly to resist
trains, and the longitudinal component of diagonal

Longitudinal girders shall generally consist of
spans less than one hundred and ten (110) feet in
trusses for longer spans.

29. *Highway Trestles*

In general, the specifications for railway trestles
designing highway trestles or viaducts, except that
sway-diagonals of towers may be made of adjust
zontal struts at the panel points, provided that the
to the columns.

30. *Camber*

All trusses must be provided with such a
full live-plus-impact load over the entire span, the
taken out by deflection. The actual deformations of
under dead load plus half live-plus-impact load
the tension members should then be fabricated
members longer than their lengths under the above
of the computed deformations. The camber of the
condition should then be figured. In railway floors,
after a span is swung may be taken out of the track
unless this would cut too deeply into the
shallow, open-webbed, riveted girders are not to be
calculating deformations the gross areas of all

Approximate methods of figuring camber
simple-span trusses.

31. *Expansion*

Every span must be provided with some
sion and contraction due to changes of tempera
hundred and fifty (150) degrees Fahrenheit in
(90) degrees in tropical ones, combined with
tom chords due to live load and impact.

Spans up to fifty (50) feet in length may slide on planed surfaces; but those of greater length must move on nests of turned rollers and must have rocker bearings.

32. *Anchorage*

Every span must be anchored at each end to the pier or abutment in such a manner as to prevent the slightest lateral motion, but so as not to interfere with the longitudinal motion of the trusses or girders due to changes of temperature or of loading. All bearings shall be secured to the masonry by fox-bolts not less than one and a quarter (1¼) inches in diameter for girder spans or one and a half (1½) inches for truss spans. When the structure is subject to possible uplift, anchor bolts, effectively attached to the superstructure, shall engage a mass of masonry, the weight of which is at least twice the greatest possible uplift.

33. *Name-Plates*

Name-plates having thereon the names of the designer, manufacturer, and builder and the date of erection must be attached in a durable manner and in a prominent position to every bridge and trestle.

LOADS

34. *Loads for Railway Bridges*

Bridges, trestles, and elevated railroads are to be designed to sustain properly the greatest stresses produced in them by any of the following loads or by any combination of them which may reasonably be expected to occur.

A. Live Load.
B. Impact Load.
C. Dead Load.
D. Uplift Load (for swing spans only).
E. Direct Wind Load.
F. Indirect Wind Load or Transferred Load.
G. Vibration Load.
H. Traction Load.
I. Centrifugal Load.
J. Effects of Changes of Temperature.

35. *Loads for Highway Bridges*

The loads to be considered in designing highway bridges and trestles are the following; and all parts of such structures are to be proportioned to sustain properly the greatest stresses produced thereby for all reasonable combinations of the various loads, excepting only that the live load and the wind load cannot act together, unless the structure carry an elec-

Live Load.

Impact Load.

Dead Load.

Uplift Load (for swing spans

Direct Wind Load.

F. Indirect Wind Load or Transferred

G. Effects of Changes of Temperature.

When a highway bridge carries an electric
tioned also for—

H. Traction Load, and

I. Centrifugal Load.

36. *Live Loads for Railway*

The live loads to be used in designing any
taken from Figs. 6*b*, 6*c*, 6*d*, and 6*e*.

In single-track bridges only one of the live
used for any span; but in bridges having more
even three classes of loading may be employed to
span; for instance, a certain heavy load could
the next lighter load for the floor-beams, and a
trusses, thus utilizing the theory of probabilities.

For elevated railroads and for the bridges of
loads are to be taken from Figs. 6*f* to 6*n*, inclusive.

The equivalent live loads given in the diagrams
and 6*g* to 6*n* inclusive are to be used in making
instead of the actual wheel concentrations.

In applying these curves, the span-lengths used

For stringers, a single-panel length; for floor-
suspenders with their corresponding secondary
lengths; for hip verticals of Petit trusses, four (4)
all main truss-members, the length of span.

In calculating the stresses caused by a uniform
load shall be assumed to cover the panel in advance
considered; but the half-panel load going to the
be ignored; or, in other words, the uniform load
concentrated at the various panel points.

In deck-spans on sharp curves, after the centre
and the centre lines of the longitudinal girders
mate extra live load, if any, on the outer girder
the curve of the rail beyond its centre line
puted and added to the regular live load; but
of dead load from the flooring, being small,

[illegible] velocity of trains, there will be an excess [illegible] load on the outer girder due to the velocity being sometimes [illegible] this, the excess of live load on the inner girder, due to the velocity [illegible] train being sometimes less than that assumed for determining the superelevation, is offset by the fact that the impact is then reduced; hence it is to be ignored.

37. *Live Loads for Highway Bridges*

The uniformly distributed live loads per square foot of floor, including the entire clear widths of both main roadway and footwalks, shall be taken from the curve diagram shown in Fig. 6o; and the concentrated live loads shall be taken from Fig. 6p. In applying the curves, the span lengths used shall be as follows:

For stringers and joists, a single panel length; for floor-beams and [illegible] suspenders with their corresponding secondary truss struts, [illegible] panel lengths; for hip verticals of Petit trusses, four (4) panel lengths; and for all main truss-members, the length of span.

[illegible] case of bridges with exterior sidewalks, one sidewalk only and [illegible] are to be considered loaded when proportioning the beams [illegible] secondary truss members of all bridges, and when proportioning the main truss-members of all spans of less than one hundred (100) [illegible] bridges of Class A, and of all spans of less than eighty (80) feet for [illegible] of Classes B and C. In all other cases both of the sidewalks and [illegible] are to be considered loaded. The eccentric loading increases [illegible] per truss. But, when a bridge has only one exterior side[illegible] effect of the eccentric loading is to be considered to act upon [illegible] of the nearer truss, and the sidewalk is to be considered empty [illegible] the stresses in the farther truss. Floor-beams of bridges [illegible] exterior sidewalks are to be proportioned on the assump[illegible] main roadway is loaded and the sidewalk or sidewalks [illegible] second, that the main roadway is empty and the side[illegible] are loaded, due account being taken of the effect of [illegible] as hereinafter specified.

[illegible] of railway bridges, in calculating the stresses caused [illegible] load, the said load shall be assumed to cover the [illegible] the panel point considered; but the half-panel load [illegible] panel point will be ignored; or, in other words, [illegible] be treated as if concentrated at the various panel

[illegible] live loads given in Fig. 6p are to apply only to the [illegible], and secondary truss members. They are sup[illegible] panel length of the main roadway to the exclu[illegible] there (excepting only the electric railway live

[illegible] The road-roller load is
all of the joists that it can cover,
two joists.

In case that the highway bridge or
that one of the train loads shown in Fig. 6
mates to the greatest electric-railway load that
by the structure is to be adopted. This live
assumed to occupy ten (10) feet in width of the
the span to the exclusion of all other live loads
The equivalent uniformly distributed live loads,
Figs. 6g to 6n inclusive, are to be used when
instead of the concentrations just specified.

The floor system and the secondary truss-
for these electric-train loads when passing either
heavy wagon-load; and the trusses as a whole
uniform load found by combining the equivalent
considering it to occupy ten (10) feet of roadway,
pact allowance, with the regular uniform live
floor on the remaining width of clear roadway,
impact allowance, provided that the equivalent
for the cars plus the proper impact allowance
for a ten (10) foot width of roadway plus its proper
it should not so exceed, the regular uniform live

38. *Impact Loads*

For steam-railway bridges the impact
the following formula,

$$I = \frac{165}{nL + 150},$$

where n is the number of tracks and L is the
which must be covered by the moving load in
mum stress on the piece under consideration. Fig.
puted from the above formula for loaded lengths
feet and for one, two, three, and four tracks.

The corresponding formula for electric-railway

$$I = \frac{120}{nL + 175},$$

and Fig. 7d gives the corresponding curves.

For highway bridges the formula is $I =$

In this case n is equal to the total clear

[illegible] by twenty (20). Fig. 7e shows the corresponding [illegible] n = 2, n = 3, and n = 4. In case that the value of [illegible] the impact can be found by interpolation. There is to be [illegible] roller loading.

[illegible] movable spans there is to be an impact allowance for dead-[illegible] amounting to twenty-five (25) per cent thereof, to be applied [illegible] that could be affected by shock due to starting the span in [illegible] to bringing it to rest; but, of course, such impact stresses will combine with the live-load stresses. In swing spans and bascules dead-load impact must be applied to all truss members and their [illegible] details; and in vertical lift bridges to the columns of the [illegible], the suspending ropes, the equalizers, the hangers, and all the [illegible] details for these parts.

39. *Dead Load*

[illegible] dead load for girders and trusses is to include the weight of all [illegible] wood, concrete, and other materials in the superstructure, ex-[illegible] of those portions resting directly on the abutments, the [illegible] which do not affect the stresses in the trusses; also any other [illegible] or temporary load (such as snow) that may be carried by [illegible]

[illegible] unit weights are to be assumed in estimating the dead [illegible]

[illegible] lumber, four and one-half (4½) pounds per foot board [illegible]

[illegible] and other hard woods, four and a quarter (4¼) pounds per foot [illegible]

[illegible] pine, three and three-quarters (3¾) pounds per foot board [illegible]

[illegible] and other soft woods, two and three-quarters (2¾) pounds [illegible] measure.

[illegible] their fastenings, seventy (70) pounds per lineal foot per [illegible] heavy rails be employed, in which case the pre-[illegible] to be properly increased.

[illegible] from one hundred and forty (140) to one hundred and [illegible] per cubic foot, according to the character of the stone [illegible] manufacture. For reinforced concrete five (5) pounds [illegible] the preceding unit weights.

[illegible] including binder, one hundred and twenty (120) [illegible]

[illegible] hundred and forty (140) pounds per cubic foot.

[illegible] and ninety (490) pounds per cubic foot.

[illegible] and fifty (450) pounds per cubic foot.

[illegible] for masonry or concrete arches), one hun-[illegible] foot.

[illegible] fifty (50) per

[illegible] (carried in pipes) sixty-two

[illegible]

[illegible] highway bridges the division of dead

[illegible] chords need be only approximate

[illegible] sufficiently accurate to assume that

[illegible] by the loaded chords.

If in any bridge design the dead load [illegible] computed from the diagram of sections [illegible] amount exceeding one (1) per cent of the sum [illegible] impact load, and actual dead load, the [illegible] to be made over with a new assumed dead load.

40. *Uplift Loads*

There is, or should be, a considerable uplift [illegible] span when it is ready for travel, caused by the [illegible] amount of this uplift per truss or girder is to be [illegible] portion of the entire dead load carried by one [illegible] girder when the span is being swung, which [illegible] the following table:

TABLE 78*b*

RATIOS OF UPLIFT TO DEAD LOAD FOR [illegible]

Spans
Up to 150′
150′ to 250′
250′ to 350′
350′ to 450′
Over 450′

These uplifts are to be adopted both for finding [illegible] trusses and for proportioning the end-lifting [illegible] ever, that for the latter purpose no assumed [illegible] than twenty thousand (20,000) pounds for [illegible] less than forty thousand (40,000) pounds for [illegible] For light highway bridges the inferior limit of [illegible] ten thousand (10,000) pounds at each of the [illegible] When uplift stresses tend to increase the sections [illegible] to be duly considered, but when they tend to [illegible] ignored.

41. *Wind Loads for Railroad Bridges*

For steam railway bridges the wind loads per lineal foot of span for both the loaded and the unloaded chords are to be taken from the curves given in Fig. 9*b*. The wind loads for the loaded chords include a pressure of three hundred (300) pounds per lineal foot on the train, the centre of which pressure is applied at a height of eight (8) feet above the base of rail. For determining the requisite anchorage for a loaded structure, the train of empty cars shall be assumed to weigh one thousand (1,000) pounds per lineal foot.

In trestle towers the columns and transverse bracing shall be proportioned to resist the following wind-pressures in addition to all other loads:

First. When the structure is loaded, six hundred (600) pounds per lineal foot on stringers and cars, concentrated at a height of one foot above base of rail, and two hundred and fifty (250) pounds for each vertical foot of each entire tower.

Second. When the structure is empty, three hundred and fifty (350) pounds per lineal foot on stringers, assumed to be concentrated one foot above the centre of stringer, and three hundred and fifty (350) pounds for each vertical foot of each entire tower.

The wind loads for longitudinal bracing are to be taken as seven-tenths (0.7) of those for the transverse bracing.

In figuring greatest tension on columns and anchor-bolts, computations are to be made for both the loaded and the unloaded structure, in double-track trestles placing the train of empty cars on the leeward track.

The wind loads of the upper lateral system shall generally be assumed to be carried to the ends of the span by the said lateral system, no part thereof being considered to travel down by the intermediate vertical sway-bracing.

All wind loads are to be treated as *moving loads*. No percentage of impact is to be added to wind loads.

Wind loads for swing spans are specified subsequently in this chapter, as are also those for the design of the machinery of vertical lift and bascule bridges.

In vertical lift bridges the towers are to be figured for a wind load of fifteen (15) pounds per square foot with the movable span in its highest position and for one of thirty (30) pounds per square foot with the said span in its lowest position, the longitudinal wind load on the span being taken as seven-tenths (0.7) of the transverse.

In bascule bridges the structural portions shall be designed for a wind load of thirty (30) pounds per square foot with the span closed, and for one of fifteen (15) pounds per square foot when the said span is in any other position.

42. Wind Lo

For highway and electric-railway
foot of span for both the loaded and
from the curves shown in Fig. 9d. The
of bridges carrying electric railways
and fifty (250) pounds per lineal foot on
pressure is applied at a height of seven (7)
These diagrams were figured for a clear
For wider structures, the wind loads for the
creased two (2) per cent for each foot of width
The wind loads given on the diagram have been
designs for simple spans up to seven hundred
but beyond this limit they have been assumed;
ing spans of greater length than this, it will be
assumed wind-pressure after the sections are
tensity of twenty-five (25) pounds per square foot
ployed in preparing the curves varied from forty
short spans to twenty-five (25) pounds for very

For viaducts carrying highway traffic only, the
empty structure is to be assumed as three
lineal foot on the spans at the level of the floor,
fifty (250) pounds for each vertical foot of each
loads for longitudinal bracing are to be taken as
those for the transverse bracing.

For elevated railroads and for viaducts carrying
wind loads are to be taken as eight-tenths (0.8)
railroad bridges.

All wind loads are to be treated as *moving loads*.

For all highway structures the live load and the
be assumed to act together, excepting only that the
load must be taken as acting in conjunction with the

Wind loads for swing spans are specified subseq
as are also those for the design of the machinery of
bridges.

The wind loads for the design of the towers of
bridges and the structural portions of bascule hi
the same as those specified for railway bridges.

43. *Indirect Wind Load or Trans*

For through truss spans with inclined end po
top chords, the transferred load is to be assum
in the leeward bottom chord that is constant
and a similar release of tension on the wind
trusses with parallel chords this assumption is

[illegible] travels directly to ends of span by the horizontal brac- [illegible] with polygonal top chords the assumption is a [illegible] travel of wind-pressure being ambiguous. The trans- [illegible] is to be found by multiplying one-half of the total wind load [illegible] top chord by the vertical distance between the point of contra- [illegible] of the inclined end post and the hip apex and dividing the product [illegible] perpendicular distance between central planes of trusses.

44. *Vibration Load*

[illegible] railway bridges the vibration load is a transverse loading, gener- [illegible] excess of the wind load, applied to the lateral bracing only. The [illegible] which it produces are not to be added to any other stresses, its [illegible] being to ensure sufficient sectional areas for lateral members [illegible] to attain proper rigidity for the structure as a whole. For the [illegible] chords of through and deck spans and for viaduct towers its value [illegible] taken as seven hundred (700) pounds per lineal foot for single- [illegible] structures and eight hundred and fifty (850) pounds per lineal foot [illegible] track structures. For the unloaded chords the corresponding [illegible] are, respectively, three hundred (300) and three hundred and [illegible]. In computing the stresses caused by vibration loads, they [illegible] to be considered as advancing.

[illegible] bridges and electric-railway bridges are not to be figured [illegible] loadings.

45. *Traction Load*

[illegible] traction load on any portion of a structure is to be taken [illegible] percentage of the greatest live load that can be placed on [illegible] of said structure. For elevated railroads and electric-rail- [illegible] this percentage is to be taken as twenty (20); and for railway [illegible] to be determined by the formula,

[illegible] $= \dfrac{4000}{140 + L}$, with $T_{max} = 20$ and $T_{min} = 10$;

[illegible] percentage,

[illegible] length in feet.

[illegible] may be taken from Fig. 9e.

[illegible] the towers and columns of railway trestles and ele- [illegible] said towers and columns between consecutive expan- [illegible] be assumed to receive no aid from neighboring towers [illegible] be figured for the greatest possible traction load [illegible] consecutive expansion points. No percentage of im- [illegible] traction loads. There is to be no traction loading [illegible] they carry electric-railway tracks.

[illegible]

where C is the centrifugal load per lineal [illegible] load per lineal foot, R is the radius of the [illegible] by the formula,

$$V = 60 - 2.5D$$

where D is the degree of curvature. The [illegible] twenty (20) degrees can be taken from Fig. [illegible]

All portions of the structure affected by the [illegible] be figured to carry properly the stresses induced [illegible] tion to all other stresses to which they may be [illegible] assumed as applied five (5) feet above the base of [illegible] of gravity of the moving load. The transferred [illegible] girders, or trusses due to the transference of the [illegible] plane of the lateral bracing shall be considered [illegible] produced in the laterals and chords forming the [illegible] rying this load to the ends of the span. The [illegible] centrifugal load on the structure as a whole shall [illegible] The effect of the shifting of the centre of gravity [illegible] superelevation of the outer rail shall also be taken [illegible] as the effect of the eccentricity of the load due to the [illegible] track. No percentage of impact is to be added to [illegible] There is to be no centrifugal loading for highway [illegible] carry electric-railway tracks.

47. *Effects of Changes of Temperature*

In ordinary structures changes of temperature [illegible] stresses in the members, provided, of course, that [illegible] taken to permit unrestricted expansion and con[illegible] arches, excepting only those hinged at both ends [illegible] stresses caused by the assumed extreme changes of [illegible] be computed and duly considered. Temperature [illegible] given proper consideration in all steel trestles in [illegible] points are placed farther apart than the length of [illegible]

WORKING STRESSES

48. *Intensities of Working Stre[illegible]*

The following intensities of working stresses [illegible] inch of cross-section) for medium and rivet [illegible] for all cases, except as hereinafter specified to [illegible]

Tension on gross sections of eye-bars and reinforcing bars, on net sections of all built members, and on net sections of flanges of all beams	16,000 lbs.
Bending on pins	27,000 lbs.
Bearing on pins	22,000 lbs.
Bearing on shop rivets	20,000 lbs.
Bearing on end stiffeners of plate girders (outstanding legs only)	16,000 lbs.
Shear on pins	15,000 lbs.
Shear on shop rivets	10,000 lbs.
Shear on plate-girder webs, gross section	10,000 lbs.
Bearing on expansion rollers, in pounds, where d is the diameter of the roller in inches	$600\,d$.

For field rivets the intensities for bearing and shear are to be reduced twenty (20) per cent.

Turned bolts with driving fit are to be stressed the same as field rivets.

Compression in pounds on struts with fixed ends, $16{,}000 - 60\frac{l}{r}$.

Compression in pounds on struts with hinged ends, $16{,}000 - 80\frac{l}{r}$.

Compression on gross section of flanges of rolled beams 16,000 lbs.

Compression in pounds on gross section of flanges of built beams, $16{,}000 - 200\frac{l}{b}$.

Compression in pounds on forked ends, $10{,}000 - 300\frac{l}{t}$.

In these compression formulæ l is the unsupported length of strut, flange, or jaw-plate in inches, r is the least radius of gyration of the strut in inches, b is the width of the flange in inches, and t is the thickness of jaw-plate in inches.

The intensities of working stresses for nickel steel, established on the basis that the least allowable elastic limit (determined by the drop of the beam) in specimen tests is 55,000 pounds per square inch for plate-and-shape steel and 60,000 pounds per square inch for eye-bar steel, are to be as follows. In case that a still higher grade of nickel steel is procurable, all the intensities, excepting those on rivets, are to be multiplied by the ratio of the higher elastic limit to 55,000 or 60,000, according to the character of the steel under consideration.

Tension on gross sections of eye-bars	28,000 lbs.
Tension on net sections of all built members, and on net sections of flanges of all beams	26,000 lbs.
Bending on pins	45,000 lbs.
Bearing on pins	35,000 lbs.

Bearing on shop rivets
Bearing on end stiffeners of plate-g
Shear on pins
Shear on shop rivets
Shear on plate-girder webs, gross section
Bearing on expansion rollers, in pounds,
diameter of the roller in inches

For field rivets and turned bolts with driving
bearing and shear are to be twenty (20) per cent
rivets.

Compression in pounds on struts with fixed

Compression in pounds on struts with hinged

Compression on gross section of flanges of rolled

Compression on gross section of flanges of built

Compression in pounds on forked ends, 16,000

In these compression formulæ, as before, l
of the strut, flange, or jaw-plate in inches, r is the
of the strut in inches, b is the width of the flange
thickness of the jaw-plate in inches.

All the preceding figures for both carbon steel
total equivalent static loads without wind loads
latter are also included the said figures in the
are to be increased thirty (30) per cent. Members
which are subjected to wind loads alone are to
as truss members for equivalent static loads with
dicated in the clause "Combination of Stresses,"
tions of loadings may legitimately stress the metal
per cent above the ordinary limits.

The intensities of working stresses for
subsequently in this chapter.

For the various kinds of timber used ordinarily
the intensities of working stresses in bending on
the proper impact is added to the live load, shall be

Long-leaf, Southern yellow pine
Douglas fir or Pacific Coast cedar
White oak
Cypress
Short-leaf yellow pine

In all cases the actual and not the nominal dimensions of timbers are to be used when figuring their strength by the preceding intensities.

49. *Bearings upon Masonry*

All bed-plates must be of such dimensions that the greatest pressures on the masonry, including impact, shall not exceed those given in the following table.

Material	Permissible Pressure per Square Inch
Ordinarily good sandstone	200 lbs.
Yellow pine or oak on flat	250 lbs.
Extra good sandstone (not metamorphic)	300 lbs.
Hard brick laid in Portland cement	350 lbs.
Ordinarily good limestone	400 lbs.
Portland cement concrete	500 lbs.
Extra good limestone	550 lbs.
Granitoid	600 lbs.
Metamorphic sandstone of best quality	650 lbs.
Granite	800 lbs.

50. *Compression and Shear in Reinforced Concrete Beams and Slabs*

The greatest intensities of simple compressive stress in reinforced concrete beams and slabs shall not exceed six hundred (600) pounds, except over the supports of continuous beams where an intensity of seven hundred (700) pounds will be permissible.

The greatest intensity of shearing stress in reinforced concrete beams and slabs shall not exceed the following values:

1. For beams and slabs with horizontal bars only and without web reinforcement, 40 pounds.
2. For beams and slabs with at least a half of the longitudinal reinforcement bent up over the supports, 60 pounds.
3. For beams and slabs thoroughly reinforced with web reinforcement, 120 pounds.

In calculating the intensity of shearing stress the depth from the centre of compression to the centre of the steel shall be used.

51. *Reversing Stresses*

In the combination of stresses of opposite kinds, distinction is to be made between the conditions of reversal. If the cause thereof be wind, the effect of reversion is to be ignored. Reversals due to live load combined with impact are to be divided into two classes: first, those which occur in succession during the passage of a live load over the structure, and, second, those which are caused by different loadings. In the first case each of the two kinds of stress is to be increased by seventy-five (75)

[illegible] procedure is similar to that just [illegible] to be added is fifty (50) instead of [illegible] area, though, when figuring the number of [illegible] [illegible], the two opposite stresses are to be [illegible] [illegible], and the sum is to be divided by the [illegible] rivet.

52. *Counter Systems*

Counter systems in all spans must be pro[illegible] increase in live load of twenty-five (25) per [illegible] stress not to exceed twenty-five (25) per cent, [illegible] being employed if required by this increased [illegible]

53. *Net Section*

The net section of a tension member must be [illegible] diagonal, and zigzag lines of rivet holes, taking [illegible] of combined shear and tension on all diagonal [illegible] area of such diagonal sections can be determined [illegible] The diameters of the rivet holes shall be assumed [illegible] diameters of the rivets before driving.

In designing built members care must be taken [illegible] of the section of any component part thereof at [illegible] rivets is not taken greater than the value of [illegible] said rivets; and that the difference between the [illegible] any two points is not taken greater than the [illegible] veloped by the connecting rivets between the said [illegible]

54. *Effective Bearing Area*

The effective bearing area of a pin, a bolt, or a [illegible] eter multiplied by the thickness of the piece, except [illegible] rivets one-half of the depth of the countersink [illegible] they are machine driven and the whole thereof when [illegible]

55. *Bending Moments and Shears on* [illegible]

Pins are to be proportioned to resist the greatest [illegible] stresses produced in them by the bars or struts wh[illegible] figuring the bending moments on pins, the stresses [illegible] concentrated at centres of bearings.

56. *Combinations of Stresses*

In plate-girder spans and the girders of ele[illegible] stresses that need to be considered are those ca[illegible] dead, and centrifugal loads. The trusses of both [illegible]

[illegible] by the centrifugal load. [illegible] structure will the traction load affect the [illegible] an extent as to need consideration; consequently the [illegible] for traction load required in through and deck bridges [illegible] rigid bracing to carry it from the track to the trusses without [illegible] any portion of the structure to an improper loading, as, for [illegible], the flanges of cross-girders to horizontal bending.

In bridges of all kinds, with the exception of arches having less than [illegible] (3) hinges, the various loads herein specified shall be combined and sections of members shall be computed as hereinbefore specified; but [illegible], more especially very high ones, it will be legitimate, when [illegible] the stresses from the various loadings, to reduce some of them even to ignore some entirely, in order to avoid proportioning for highly [illegible] or impossible combinations of loads. For instance, when a [illegible] is situated near the middle of a sharp curve or near the apex of [illegible] grades, it would be incorrect to assume a high velocity [illegible]. In such cases as these the element of individual judgment in [illegible] the stresses from the various loads and in assuming the sizes [illegible] cannot well be eliminated.

[illegible] ordinary conditions the figuring of stresses and sectional areas [illegible] columns of trestles shall be done as follows:

[illegible] load, impact, centrifugal load, and dead load, with the [illegible]

[illegible] Live load, impact, centrifugal load, dead load, and wind [illegible] load, or temperature effect, with an excess of thirty (30) [illegible] the usual intensities.

[illegible] load, impact, centrifugal load, dead load, wind load or [illegible] and temperature, with an excess of forty (40) per cent over [illegible]

[illegible] load, impact, centrifugal load, dead load, traction load, [illegible] with an excess of forty (40) per cent over the usual in- [illegible]

[illegible] load, impact, centrifugal load, dead load, traction load, [illegible] temperature, with an excess of fifty (50) per cent over [illegible]

[illegible] adjustment of combinations of stresses and intensities [illegible] shall apply also to arch structures having less than [illegible] per arch.

[illegible] stress shall be allowed for a combination of wind [illegible] stresses only, or for a combination of traction [illegible] only; but for combined wind and traction stresses [illegible] traction, and centrifugal stresses an increase in [illegible] (30) per cent will be allowed. These restrictions [illegible] system between the loaded chords.

When combining bending stresses chords of riveted truss bridges subjected be employed the compromise formula

$$M = \frac{Wl}{10},$$

for finding the bending moment; and the exceeded for the combination of extreme fibre pression or tension.

In the case of chords of pin-connected considered free, the corresponding compromise

but if the chords are continuous, the formula to

In these two formulæ M is the bending is the total load in pounds on the beam, and l is the between panel-points or supports.

In computing the bending moment due to mula is to be $M = \frac{Wl}{12}$ for riveted trusses, M

trusses with free ends, and $M = \frac{Wl}{10}$ when the chords

57. *Bending on Inclined End Posts*

In proportioning inclined end posts of trusses a combination of all the loads herein specified, caused by the wind-pressure which travels to the pier or abutment, the extreme fibre may be per cent higher than the intensity specified for the the bending moment being computed on the end post is held in line by the top and the bottom bracing and fixed at the bottom by its connections the end floor-beam. The position of the point of taken from Fig. 16*d*.

58. *Bending Due to Weight of M*

If the extreme fibre-stress resulting from the only of any member does not exceed ten (10) intensity of working-stress, the effect of such but, if it does so exceed, its effect must be other stresses, using, however, for determining intensity of working stress ten (10) per cent

59. *General Limits in Designing Railway Structures*

No metal less than three-eighths ($\frac{3}{8}$) of an inch in thickness shall be used, except for filling-plates.

No channel less than ten (10) inches in depth shall be used except for lateral struts, in which eight (8) inch channels may be employed.

No angles less than $3'' \times 2\frac{1}{2}'' \times \frac{3}{8}''$ shall be used, except for lacing. The length of unsupported outstanding legs of angles in compression shall not exceed twelve (12) times their thickness for main members or sixteen (16) times their thickness for lateral bracing.

No eye-bars less than six (6) inches deep or one inch thick shall be employed; and the depths of eye-bars for chords and main diagonals shall be not less than one fifty-fifth ($\frac{1}{55}$) of the length of the horizontal projection of same.

The shortest span length for trusses with polygonal top chords shall be one hundred and seventy-five (175) feet.

The limit of span length in which the stringers can be riveted continuously from end to end of span shall be two hundred (200) feet. Beyond this limit sliding bearings must be used at one or more intermediate panel points; and in no span shall there be a length of continuously riveted stringers exceeding two hundred (200) feet.

For all compression-members of trusses and for columns of viaducts and elevated railroads the greatest ratio of unsupported length to least radius of gyration shall be one hundred (100), excepting those members the main function of which is to resist tension. In these the limit may be raised to one hundred and twenty (120).

The greatest ratio of unsupported length to least radius of gyration for struts belonging to sway bracing shall be one hundred and twenty (120).

For all horizontal or inclined main or bracing members in tension, the length of the horizontal projection of the unsupported portion of the member shall not exceed one hundred and fifty (150) times the radius of gyration about the horizontal axis.

60. *General Limits in Designing Highway Structures*

The following general limits shall be adhered to in designing highway bridges and viaducts.

The length of any bracket cantilevered beyond a truss or girder shall never exceed seven-tenths ($\frac{7}{10}$) of the perpendicular distance between the central planes of adjacent trusses or girders, unless there be more than two trusses to the span.

No metal less than five-sixteenths ($\frac{5}{16}$) of an inch in thickness shall be used, except for filling-plates; and in important bridges this limit shall be increased to three-eighths ($\frac{3}{8}$) of an inch.

No channel less than six (6) inches in depth shall be used, except for lateral struts, in which five (5) inch channels may be employed.

[illegible]

chords in compression shall not exceed that for main members nor sixteen (16) bracing [illegible]

No eye-bars less than four (4) inches an inch thick shall be employed; and the and main diagonals shall be not less than zontal length of same.

No adjustable rod shall have less than inch of cross-section.

The shortest span length for trusses with be one hundred and sixty (160) feet.

The limit of span length in which steel tinuously from end to end of span shall be two yond this limit sliding bearings must be used at panel points; and in no span shall there be a length stringers exceeding two hundred (200) feet.

For all compression-members of trusses and the greatest ratio of unsupported length to least be one hundred and twenty (120), excepting function of which is to resist tension. In these to one hundred and forty (140). The greatest ratio to least radius of gyration for struts belonging one hundred and forty (140).

For all horizontal or inclined main or bracing length of the horizontal projection of the member shall not exceed two hundred (200) times about the horizontal axis.

61. *Smoke Protection*

Metal which is subjected to the action of locomotive corrosive gases, in addition to being extra well thickness increased either one-sixteenth ($\frac{1}{16}$) or, (⅛) of an inch; otherwise all paint shall be omitted tection used instead.

62. *General Principles in Designing*

In designing all structural metalwork the invariably to be observed:

All members must be straight between panel or ties will under no circumstances be allowed, arched ribs.

[illegible]

[illegible] at any apex of a truss or girder [illegible] such an arrangement is practicable; otherwise [illegible] employed to ensure that all the induced stresses [illegible] caused by the eccentricity be properly provided for. [illegible] and portions of truss members must always be ar- [illegible] in pairs symmetrically about the central plane of the truss, except [illegible] of single members, the axes of which lie in the said central [illegible]. This applies also to the designing of open-webbed, riveted [illegible]

[illegible] proportioning main members of bridges, symmetry of section about [illegible] planes at right angles to each other is to be attained wherever [illegible]; but in designing top chords and inclined end posts this rule [illegible] generally be followed.

[illegible] both tension and compression members, the centre line of applied [illegible] invariably coincide with the axial right line passing through [illegible] of gravity of all cross-sections of the members taken at right [illegible].

[illegible] principle of symmetry in designing must be carried even into the [illegible] and groups of rivets must be made to balance about centre [illegible] planes to as great an extent as is practicable.

[illegible] structural metalwork, excepting only the machinery for oper- [illegible] bridges, no torsion on any member shall be permitted, if [illegible] be avoided; otherwise, the greatest care must be taken to [illegible] strength and rigidity for every portion of the structure [illegible] such torsion.

[illegible] all pin-connected work ample clearance for packing must [illegible] and sufficient room must be left for assembling members in [illegible].

[illegible], trestles, and elevated railroads the thrust from braked [illegible] traction must be carried from the stringers or longitudinal [illegible] posts or columns without producing any horizontal bending [illegible] cross-girders or the lateral diagonals.

[illegible] elevated railroads, the columns must be carried up to [illegible] the cross-girders or longitudinal girders, and must be effec- [illegible]. In no case will it be permitted to cut off the [illegible] the cross-girders or longitudinal girders on top of same.

[illegible] that acts also as a beam must have a solid web or webs [illegible] the bending, as no reliance shall be placed on lacing [illegible] load down the column.

[illegible] elevated railroads every column must be anchored so [illegible] that failure by overturning or rupture could not [illegible] of the foot, if the bent were tested to destruction.

[illegible] riveting must be reduced to a minimum, without, [illegible] the number of rivets requisite for strength and

rigidity. All designs are to be made
much as possible.

Rivets are not to be used in direct

For members of any importance,
for each connection.

In designing short members of open-
to increase the sectional area of the piece
(25) per cent beyond the theoretical
the strength by using supplementary angles
the plates.

The efficiency of single-angle members in
sixty (60) per cent, and of two-angle members
per cent when fastened to the connection plate
the legs which are adjacent to each other, and
when fastened by the legs not adjacent to each
members the corresponding percentages shall be
and fifty (50).

Star struts formed of two angles with occasional
or plate for staying the same are not to be used,
obtained by placing the angles in the form of a T.

Compression splices, where only a portion of
where, consequently, perfect abutting of the
and tension shingle splices shall have a strength
cess of that of the section cut; but compression
section is cut and where perfect abutting of
have a strength at least equal to sixty (60) per
section. The splice must be figured to ensure that
erly of the greatest transverse bending to which it

Tension splices in which the entire section is
have a strength equal to that of the cut section.

In all splices and connections the arrangement
metal must be such as to make the splice or
part have at least the same proportional strength

In all main members having an excess of
by the greatest combination of stresses, the
portioned to correspond with the utmost working
and not merely for the greatest total stress to
In this connection, though, the reduced capacity
by one leg only must not be forgotten.

Designs must invariably be made so that all
shall be accessible to the paint-brush, excepting
which are in contact with each other or with the
ment rules out all closed columns of every type

The bottom flanges of all girder spans and
the masonry by not less than six (6) inches.

In general, details must always be proportioned to resist every direct and indirect stress that may ever come upon them under any probable circumstances, without subjecting any portion of their material to a stress greater than the legitimate corresponding working-stress.

In all designs simplicity in both main members and details is to be considered of the greatest importance.

In all structures rigidity is to be deemed quite as important an element as mere strength.

Structures on skews are to be avoided whenever it is practicable to do so.

The use of more than a single system of cancellation in bridges shall be confined entirely to lateral systems and sway-bracing, except that at mid-panels of trusses two rigid diagonals connected at their intersection may, for appearance, be employed, provided that either diagonal shall have sufficient strength to carry the entire shear in tension, and that the adjacent vertical posts be figured accordingly.

The use of redundant members in structures shall not be allowed, excepting only in the case just mentioned of rigid mid-panel diagonals.

In all designing true economy must be given the utmost consideration, and no useless material must be employed, every pound of metal in the structure having a legitimate function; but economy of material must not be quoted as an excuse for using inferior details or scamping the work in respect to strength, rigidity, or appearance.

In all structural work the subject of æsthetics must be duly considered; and all designs are to be made in harmony with the principles thereof, to as great an extent as the money available for the work will permit or as the environment of the structure calls for.

63. *Riveting*

In railway bridges the rivets used shall generally be seven-eighths (⅞) inch in diameter, smaller ones being employed for small channel flanges and legs of angle-irons less than three (3) inches wide. In heavy work the rivet diameter should be increased to one inch, and in very heavy work to one and an eighth (1⅛) or even one and a quarter (1¼) inches. In highway bridges for ordinary work the rivet diameters may be made three-quarters (¾) of an inch.

For very long grips tapered rivets are to be employed.

The proper diameters for rivets in flanges of channels are as follows:

Depth of channel.....	6″	7″	8″	9″	10″	12″	15″
Diameter of rivet.....	⅝″	⅝″	¾″	¾″	¾″	¾″	⅞″

The pitch of rivets in all classes of work in the direction of the stress shall never exceed six (6) inches, or sixteen (16) times the thickness of the thinnest outside plate, nor ever be less than three (3) diameters of

[illegible]

[illegible] shall less rivets be used
[illegible] two angles, however, a
[illegible] for riveting the said two angles
[illegible] two or more thicknesses of plate
[illegible] members, the outer row of rivets shall
[illegible] from the side edge of the plate.

In flanges of plate-girders and chords,
shall not exceed four (4) inches.

No rivet-hole centre shall be less than
from the edge of a plate, and, whenever
be increased to two (2) diameters.

The rivets when driven must completely

The rivet-heads must, in general, be round
uniform size for the same-sized rivets throughout
be neatly made and concentric with the rivet-hole
pinch the connected pieces together.

Rivets with flat heads shall be preferred
height or thickness of the flat head shall be
inch.

In important members rivets shall not be
thickness less than one-half of the diameter of
flattened heads shall be assumed to have only
strength of rivets that have full heads.

Flanges of stringers and girders carrying the
ties shall have enough rivets to transmit properly
and the vertical shears from flange to web.

Rivets carrying calculated stress and having a
diameters shall be increased in number at least
additional sixteenth inch of grip.

Wherever possible, all shop rivets shall be
machines must be capable of retaining the applied
upsetting is completed.

Field-riveting must be done with a button
rivets must be hemispherical, and no rough edges

Wherever possible, all field rivets shall be
power.

All rivets in splice or tension joints are to be
so that each half of any tension member or splice
same uncut area on each side of its centre line.

No rivet is to have a less diameter than the
plate through which it passes, unless the holes be

The effective diameter of any rivet shall be

[illegible] making deductions [illegible] diameter of the holes shall be assumed [illegible] than that of the rivet. In the effective [illegible] bolt and rivet holes shall be counted out for [illegible] holes shall be counted out for compression.

[illegible] Details of Design for Rolled I-Beam Railway Spans

Rolled I-beams used as longitudinal girders shall have, preferably, [illegible] not less than one-twelfth (1/12) of the span. They shall be [illegible] by their moments of inertia. The unsupported length of the [illegible] shall not exceed twelve (12) times its width. Either one [illegible] per rail will generally be used. In the former case the spacing [illegible] be six (6) feet six (6) inches, and in the latter case the two beams [illegible] a rail should be spaced symmetrically about the centre line of [illegible] rail, preferably with a distance of two (2) feet six (6) inches between [illegible] girders. Three beams per rail may be used where a very long [illegible] shallow floor is necessary; and in this case one of the beams [illegible] placed directly under the rail, and the other two spaced symmetrically about the centre line of said rail, and preferably one (1) foot [illegible] from it. Where a concrete slab encasing the beams sol[illegible] employed, no bracing of any kind is necessary. In case a concrete [illegible] top of the beams and grips their top flanges effectively, the [illegible] required will be a frame at each end; and this may be omitted [illegible] of the beams are encased solidly in the abutments. Where a [illegible] is adopted, there shall be a bracing frame at each end, and [illegible] shall be stayed by diagonal bracing of angles, riveted to [illegible] beams as near to the top flange as is practicable. Where [illegible] beams per track are employed, the bracing should be placed [illegible] inner beams only, and solid web diaphragms should be [illegible] the beams carrying each rail at each panel-point of the [illegible] I-beam is to have at each end a pair of stiffening angles, [illegible] ones in case the end shear require it. These angles [illegible] both top and bottom against the flanges. Under each [illegible] there is to be riveted a bearing plate of proper area [illegible] less than three-quarters [¾] of an inch) to distribute [illegible] over the masonry, the said plate to be continuous under [illegible] support each rail; and it is to be bolted to the masonry [illegible] per beam, one and one-quarter (1¼) inches in diameter, [illegible] foot into the masonry. Where the ends of the [illegible] in the concrete of the abutments, the bearing [illegible] and in this case the end stiffeners are unnecessary [illegible] alone are able to distribute the load properly [illegible] end stiffeners may also be omitted in case a [illegible] beams solidly be used.

65. *Details of Design for Rolled-I-Beam*

Rolled I-beams used as longitudinal girders shall
depth not less than one-fifteenth (1/15) of the span.
portioned by their moments of inertia. The spacing
exceed three (3) feet six (6) inches for wooden floors or
reinforced concrete base. The specifications for railway
gen in general; but except in the case of a structure
way tracks on an open timber deck, the floor should be
stiffen the top flanges of the beams effectively, and all
should be omitted. The bearing plate at each end of
be as thin as five-eighths (5/8) inch, and generally there
plate for each beam. Two fox bolts per beam shall be
and one-quarter (1¼) inches in diameter and extending
the masonry.

66. *Details of Design for Plate-Girder Railway*

Plate-girders shall have, preferably, a depth not less
(1/10) of the span. All plate-girders, whenever it is
built without splices in the web; and when such
smallest possible number of them shall be adopted.
rivets for the splices shall be such as to develop in
strength of the net section of the web, the main
from flange to flange and having generally three (3)
side of the joint, and being figured to take care of the
of the portion of the web they cover, and also the
the entire web. The bending strength of the portion of
by the flanges shall be cared for either by splice-plates
tical legs of the flange angles, or else by the excess
at that point. There must be sufficient rivets
develop the bending strength in a distance not greater
the stresses on the said rivets due to the increment of
duly considered.

Splices in flange-plates and angles must always be
ficiently long plates and angles are procurable. Where
unavoidable, they must be so located that no two
flange or the web shall be spliced within two (2) feet
so that no flange-splice shall occur at any point
excess of sectional area above the theoretical
continuous flange-piece shall be fully spliced so that
and rivets shall have a calculated strength at least
than that of the section spliced. Field-splicing of
be allowed for fixed spans, except in structures for

At least forty (40) per cent, and preferably
section must consist of angles or of angles and

[illegible] avoided whenever possible. The number of cover-plates [illegible] as small as practicable, in no case exceeding three (3) per flange. The lengths of these cover-plates must be such as to make them project at each end not less than eighteen (18) inches beyond the point determined by the calculations for the requisite resistance to bending.

Where two or three cover-plates per flange are used, they shall be of equal thickness, or shall decrease in thickness outward from the angles. The cover-plates shall not extend more than four (4) inches or eight (8) times the thickness of the outer plate beyond the outer line of rivets. With cover-plates more than fourteen (14) inches wide, four (4) lines of rivets shall be used.

The compression-flanges of plate-girders shall generally be made of the same gross section as the tension-flanges; and they shall, preferably, be so stiffened laterally that this section will be sufficient. The unsupported length of the compression flange shall not exceed twelve (12) times its width for deck girders on tangent and for through girders; but for deck structures on curves the said unsupported length shall not exceed six (6) times the said width. For deck girders supporting ties on the top flanges it is generally best to avoid the use of cover-plates. Where two angles fail to provide sufficient section, the flange should be composed of four angles with the edges of the vertical legs in contact and having side-plates riveted on these vertical legs when required.

In deck-spans there are to be bracing frames at the ends, and in spans of thirty (30) feet and over also at intermediate points not more than [illegible] (15) feet apart; and there is to be an effective system of diagonal [illegible] of angles between the top flanges of the contiguous girders for [illegible]. For deck spans of seventy (70) feet and over there is to be [illegible] system of diagonal bracing between the bottom flanges.

[illegible] double-track deck-spans over sixty-five (65) feet long, a system [illegible] bracing shall be used between the two inner girders, as well [illegible] each pair of girders under each track. Intermediate bracing [illegible] shall not be used between the girders of adjacent tracks.

[illegible] through spans the girders are to be divided into panels not [illegible] in length twelve (12) times the width of the flange, and there [illegible] bracket of web plate and angles at each end of each cross-girder [illegible] the top flange of the longitudinal girder, so as to stay the [illegible]. This bracket must extend inward to the standard clear-[illegible] will not be permissible to dispense with the steel stringers [illegible] ties on the bottom flanges or upon special shelf angles.

[illegible] plate-girder spans are generally to have a rigid, double-can-[illegible] lateral-system of angles riveted together by plates and [illegible] intersections and to the bottom flanges of the steel stringers, [illegible] employed; but if a steel trough floor be used, the laterals [illegible]. In this last case brackets similar to those above [illegible] spaced shall be riveted to the troughs.

[illegible]

[illegible] of any web plate shall [illegible] of the unsupported distance between [illegible] one-half (½) inch unless a greater thickness [illegible]

Web-stiffeners shall be placed at the ends of [illegible] at all points of concentrated loading and at intermediate [illegible] tances not exceeding either the depth of the girder [illegible] in the case of shallow girders where the shear [illegible] not exceed five thousand (5,000) pounds per square inch. Under such circumstances the spacing of intermediate [illegible] made as great as three (3) feet six (6) inches. All [illegible] tightly at top and bottom against the flange angles. [illegible] there must be fillers flush with the flange angles, but [illegible] eners shall, preferably, be crimped. All stiffeners must [illegible] stiffening angles shall extend as nearly as practicable [illegible] of the flange angles. They must have sufficient area in [illegible] legs only to carry the entire end shear, including impact [illegible] fied intensity of working-stress, no reliance being placed [illegible] The latter shall have the same thickness as the flange [illegible] tions of intermediate stiffening angles shall not be less [illegible] in the following table:

TABLE 78c

INTERMEDIATE STIFFENERS FOR GIRDERS

Outstanding Leg of Flange Angle	[illegible]
8″—for girders over nine (9) feet in depth	[illegible]
8″—for girders up to nine (9) feet in depth	[illegible]
6″	[illegible]
5″	[illegible]
4″ and under	[illegible]

In proportioning the flanges of plate girders, one-eigh[illegible] gross area of the web is to be assumed as concentrated [illegible] gravity of each flange; or, in other words, after having [illegible] sectional area required for the tension-flange by ignoring [illegible] of the web to bending, there is to be subtracted therefrom [illegible] (⅛) of the gross area of the web-plate.

At the ends of all plate girders there must be sufficient [illegible] flange to transfer properly thereto from the web the [illegible] total end shear and the vertical load thereon in a distance [illegible] effective depth of the girder.

At the ends of cover-plates the spacing of the [illegible] the covers, for a length equal to at least twice the [illegible] not exceed three (3) inches.

[illegible] plate girder a steel casting at least six (6) [illegible] be figured so as effectively to distribute the load [illegible] upon the masonry. A sole plate three-quarters (¾) of an inch [illegible] riveted to the bottom flange of the girder, and shall bear directly on the said casting, the bottom surface of the sole plate and the top surface of the casting being planed longitudinally. The girder shall be bolted to the casting with due provision for expansion and contraction, and the casting is to be bolted to the masonry with two (2) fox bolts, one and one-quarter (1¼) inches in diameter, extending eighteen (18) inches thereinto. Girders fifty (50) feet long and over are to have rocker-ends and rollers. These shoes shall be so designed as to prevent any transverse motion or possible uplifting. The minimum allowable diameter of rollers shall be six (6) inches, and they must be enclosed in dust tight boxes. Each shoe must be bolted to the masonry by four (4) fox bolts, one and one-quarter (1¼) inches in diameter, extending eighteen (18) inches thereinto.

Girders on an inclined grade without pin shoes shall have the sole plates beveled so as to make the sliding surface horizontal.

Details of Design for Highway, Plate-Girder Spans Without Steel Floor Systems

In designing a span of this type, the specifications for railway plate-girder spans are to be followed in general. The depths of the girders should, preferably, be not less than one-twelfth ($^1/_{12}$) of their span. The [illegible] of metal five-sixteenths ($^5/_{16}$) inch thick will generally be permissible, and for light girders intermediate stiffening angles as small as two and a half (2½) by two and a half (2½) inches may be used. For light, cheap [illegible] the diagonals of the lateral systems and sway frames may be [illegible] of adjustable rods. The minimum diameter of rollers in expansion [illegible] be four (4) inches. For light structures rocker-ends and rollers [illegible] required only in spans exceeding seventy (70) feet in length.

[illegible] of Design for Highway, Plate-Girder Spans with Steel Floor Systems

[illegible] of this type there will generally be two lines of longitu- [illegible] placed at about the quarter-points of the cross-section, the [illegible] of the roadway being supported by cross-girders between [illegible], while the outer portions are carried on cantilever brackets [illegible] of each cross-girder.

[illegible] should, preferably, be rolled I-beams or channels, the [illegible] used for intermediate stringers, and the latter for [illegible] the sides of the structure. They shall be proportioned [illegible] of inertia. Their length shall, preferably, not exceed

[illegible] (11) times their depth. The decking
stiffen their top flanges effectively, if possible
must be supported laterally at points spaced not
times their width. They shall generally be riveted
cross-girders or cantilevers; but if they be set up
will rarely be necessary except for sidewalk stringers
braced transversely by bracket plates riveted to the
the cantilever beams. The end stiffeners are to be
treated so as to ensure that the stringers will be of
that they will have a uniform bearing against the webs
or cantilever brackets.

The cross-girders and cantilever beams shall preferably
In general, they will be designed in accordance with
previously given for the girders of railroad plate-girder
imum thickness of metal is to be five-sixteenths (5/16) of
minimum size of angle used for intermediate stiffeners
(2½) by two and a half (2½) inches. Due consideration
to the effects on the floor-beam of live loads on the
in figuring the rivet pitches in the flanges of the
account shall be taken of the effect of the inclination
The effect of vertical loads on the top flanges of
lever beams must be considered when figuring rivet
stiffeners are to be faced or otherwise treated so as to
will have a uniform bearing against the webs of the
the bottom flanges of the cantilever brackets are to be
a full bearing on the said webs. The bottom flanges
must be similarly faced when, as is usual, the cantilever
the same depth as the cross-girder. When the cantilever
two horizontal angles milled to bear on the end stiffeners
cross-girder shall be placed on the cross-girder web
flange of the cantilever. These angles shall have sufficient
outstanding legs to carry the entire thrust from the
of the cantilever, and shall be connected to the web
by a sufficient number of rivets to transfer thereto the
angles shall not be crimped, but shall have fillers under
The entire tension from the top flange of the cantilever
for by a strap plate riveted to the top flange of the
cantilever, which shall preferably be at the same elevation
the top of the upper flange of the main girder
elevation.

The top flanges of the cross-girders are to be stayed
not to exceed twelve (12) times their widths, and
that the gross section of the tension flange will
sion flange. These supports will generally be furnished
or by the flooring directly. The bottom flange

[illegible] there is considerable stress reversal with live loads on the cantilever only. The bottom flange of the cantilever is to be so stayed that the unsupported length shall not exceed twelve (12) times its width. This support is usually to be furnished by a stringer, a bracket plate on the end of the stringer being riveted to a full-depth stiffener angle on the cantilever in case the stringer does not extend down to the bottom flange. When a concrete floor slab is used, this will stay the stringers longitudinally; otherwise diagonal bracing between the outside lines of stringers and the main girders must be adopted in one panel per span.

The lateral system is usually to consist of a double-cancellation system of rigid diagonals at the elevation of the bottom of the floor-beams. These diagonals are generally to be composed of two angles riveted back to back. No provision for traction forces will be necessary, unless the structures carry electric railway tracks on an open timber deck. In this case one horizontal truss per span is to be formed at the elevation of the bottom of the stringers carrying the electric railway, to transfer the traction loads to the main girders. The laterals should be utilized for a portion of this truss, in case they are close to the bottom of the stringers.

[illegible] each end of each end floor-beam there is to be provided a solid-web bracket riveted to the bottom flange of the floor-beam and to the end stiffeners or web of the main girder, in order to transfer the transverse loads down to the shoes. Should there be no end floor-beam at one end of the girder, an open-web bracing frame should be riveted to the end stiffeners, extending up as high as the stringers will permit. In long spans there should be used, at each end of each intermediate floor-beam, a diagonal brace of one or two angles extending from the bottom of said floor-beam down to the bottom flange.

The design of the main girders shall in general conform to the specifications for the girders of railroad plate-girder spans. Metal as thin as [illegible] ($\frac{5}{16}$) inch may be used. The length should preferably [illegible] twelve (12) times the depth. The top flange should be so [illegible] that the unsupported length will not exceed twelve (12) times its [illegible], preferably, so that the gross area of the bottom flange will [illegible] that of the upper flange. In case a concrete floor-slab is used, [illegible] on the top flange, so as to stay it effectively; but with a [illegible] no reliance can be placed on the stiffness of the floor, and [illegible] shall be assumed to be stayed only by the cross-girders, [illegible] diagonal bracing of angles be employed to stiffen it at the [illegible] panel.

[illegible] of the shoes must conform to the specifications for rail[illegible] spans, except that for light structures the diameter of [illegible] as small as four (4) inches, and that rocker-ends and [illegible] used only for spans exceeding seventy (70) feet in

[illegible] of the span for railway bridges [illegible] span for highway bridges [illegible] and flanges to reduce the deflection [illegible] the above limiting depths. A similar [illegible] I-beam spans when the depths are [illegible] (1/16) and one-eighteenth (1/18) of the [illegible]

70. *Details of Design for Open-Webbed,* [illegible]

[illegible] open-webbed, riveted girders shall be riveted [illegible] whenever possible, as field-riveting will [illegible] lateral bracing, except in structures for foreign [illegible] for any reason, this method is impracticable, all of the [illegible] have to be assembled in the shop, after which the [illegible] sections shall be reamed so as to ensure perfect [illegible] use of shallow, open-webbed, riveted girders shall [illegible] possible, for the reason that they are quite as [illegible] satisfactory as plate girders. In case, though, of their [illegible] for instance in elevated railroads occupying city [illegible] provided with short, substantial web-plates at the [illegible] mediate points where connections are made to other [illegible] will it be permissible to use flats instead of angles for [illegible] tees may be employed, provided their heads be wide [illegible] satisfactory riveted connections.

At all intersections of web-members with chords, [illegible] plates are to be used; for it is not permissible to attach [illegible] to chord angles without using an intermediary plate. [illegible] gusset plates shall be proportionate to the stresses [illegible] their resistance both to shearing out through the [illegible] the direct and the bending stresses induced by the [illegible] to them shall invariably be ample. The exact inter[illegible] all the gravity lines of girder-members assembling [illegible] adhered to in the designing of open-webbed, riveted [illegible]

In designing all riveted connections, the greatest [illegible] to make connecting plates and groups of rivets balance [illegible] of stress, especially where passing from riveted work [illegible] in the case of a riveted span with hinged ends at pede[illegible]

In all other particulars, the designing of open-[illegible] is to comply, wherever practicable and proper, with [illegible] plate-girder and riveted-truss spans.

[illegible] the top chords and those of the inclined end posts [illegible] shall consist, generally, of two built channels and a cover-plate, each channel being formed of a web and two angles, the upper one small and the lower one much larger, so as to bring the centre of gravity of the entire box section of the member as close as possible to the [illegible] plane of the web-plates. In no case will more than one cover-plate be allowed, and this is to be made as thin as is proper.

Main vertical posts shall, generally, be composed of two laced channels, preferably rolled ones, although built ones must be used where large sections are required. Secondary vertical posts may be built of two rolled channels laced, or of four angles in the form of an I with either a single line of lacing or a web. The channels of vertical posts should usually have their flanges turned inward.

Main diagonals shall generally be composed of two rolled or built channels, except for the intersecting diagonals in the centre panel of a truss with an odd number of panels, which should usually be composed of four angles in the form of an I. Secondary diagonals may be made of either two channels—generally rolled—or four angles in the form of an I. All diagonals which have to sustain compression must be laced, but sometimes the use of batten plates about three (3) feet from centre to centre will be satisfactory. The channels of diagonals will ordinarily have their flanges turned inward.

[illegible] will generally be composed of four angles in the form of an I, with a central web or a single line of batten plates. For heavy sections, [illegible] of two rolled or built channels, with two lines of batten plates, may be necessary. These channels will generally have their flanges turned [illegible]

[illegible] bottom chords in short span bridges will usually be composed [illegible] angles in the form of an I, with a single line of lacing in the end [illegible] batten plates in the central panels. The use of a central [illegible] often advisable; and when employed, drain-holes about two [illegible] diameter should be used, spaced about three (3) feet from [illegible]. For longer spans the bottom chords shall generally be [illegible] built channels having the flanges turned inward, with two [illegible] in the end panels, and two lines of batten plates in the [illegible]

[illegible] lateral struts, overhead transverse struts, and web-stiffening [illegible] preferably, be made of four angles with one line of lacing. [illegible], the said angles be spaced very far apart, as in lateral [illegible] unusually deep top chords, they are to be placed on the [illegible] rectangle, with their legs inward, and laced on all four faces [illegible] thus formed.

[illegible] two angles riveted back to back, or even a single large

angle, may be used for lower lateral diagonals
said diagonals are preferably to be made of
I, with a single line of lacing. When two angles
must not be depended on to form the splice
diagonals, but there must be employed also a
hitch angles which rivet in the field to the vertical
angles.

Diagonals for upper lateral systems and vertical
preferably, be built of four angles in the form of
of lacing; but, for structures where this section
extravagant use of metal, two of the angles, one at top
may be omitted, thus making each strut consist of
vided, of course, that where the struts cross they
nected by two plates of ample size. This unbalanced
diagonals is to be avoided whenever it can be done
of metal. In no case, though, will it be permissible
sion that are not capable of properly resisting compression
due regard for the specified limit of ratio of unsupported
radius of gyration.

In designing transverse lateral and overhead struts
tions it must be remembered that their main function
the chords or posts to place and line, and not merely
the greatest calculated direct stresses to which they
For this reason such struts must have ample section
the connecting plates at their ends must grip both
effectively.

Stringers for truss-bridges shall almost invariably
and angles, and no cover-plates will be allowed for
depths shall be made not less than the most economic
weight of metal required, provided that the bridge
and never less than one-twelfth ($^1/_{12}$) of the span.
allowed in their flanges nor any in their webs, provided
long web-plates are procurable. The compression-flanges
of the same gross section as the tension-flanges; and
stiffened that this section shall be ample to care for the
and under no circumstances shall the unsupported length
(12) times the width of flange. Rigid diagonal bracing
variably to be used between the top flanges of stringers,
frames are to be employed at all expansion points.
exceed thirty (30) feet, there shall be a bracing-frame
tween the stringers pertaining to each track, but not
adjacent tracks. In respect to intermediate stiffening
the rules governing those for plate-girder spans are
the end stiffeners are to be faced or otherwise treated
stringers of exact length throughout, and so as to

[illegible] against the webs of the cross-girders. In through [illegible] corresponding legs of the end stiffening angles of the stringers [illegible] six (6) or seven (7) inches wide with the rivets placed [illegible] the tips of said legs as is proper.

In respect to proportioning of flanges and number of rivets required, the rules given for plate-girder spans are to apply also to stringers. The said rules are to apply also to cross-girders, as shall also those relating to stiffeners, splices, cover-plates, and size of compression-flanges that are given for plate-girder spans. Wherever it is necessary to notch out the corners of the cross-girders to clear the chords or the end pins, the greatest care must be taken to provide an adequate means for transferring the shear to the posts without impairing either the strength or the rigidity. If necessary, in through-bridges the web of the cross-girder can be divided into three parts so as to let the end portions project above the top flange and form brackets that will afford opportunity for using an ample number of rivets to connect to the posts, and that will strengthen properly the otherwise weakened cross-girder.

In order to carry the thrust of trains from the stringers to the trusses through the lower lateral diagonals, the latter and the stringers are to be made to form complete horizontal trusses by running angles between stringers at the level of the bottom flanges. In single-track bridges two pieces of angle per panel running transversely between stringers at the intersection of the latter with the diagonals will suffice; but in double-track bridges there will be required one such angle per panel between inner stringers, two diagonal angles per panel to run from where the lateral diagonals intersect the outer stringers to where the inner stringers meet the cross-girders, and either one or two diagonal angles per panel running from where one inner stringer meets the cross-girder to where the other inner stringer meets the lateral diagonal. In other words, only [illegible] of each panel is to be provided with traction bracing.

[illegible] plates, angles, and channels used in built members of trusses must, [illegible] be ordered the full length of the piece; otherwise, the [illegible] splices must develop one and one-tenth ($1\frac{1}{10}$) times the full [illegible] of the portion cut, without any reliance being placed on abut[illegible] for carrying compression.

[illegible] splices at the ends of compression members, where the entire [illegible] at one point and the ends are faced, the detailing must be [illegible] for at least sixty (60) per cent of the capacity of the member; [illegible] total splices at the ends of tension members, for one hun[illegible] cent of the said capacity. In total shingle splices in either [illegible] pression members, the detailing must be proportioned for [illegible] dred and ten (110) per cent of the total strength of the [illegible]

[illegible] widths of plates stressed in compression, measuring [illegible] of rivets, shall not exceed thirty-two (32) times

[illegible]

that are used solely for making the
shall in no case be spaced more than
or from other rivets connecting the same
[illegible]. The least allowable thickness for
shall be seven-eighths (7/8) of an inch.
The open sides of all compression members
of built channels, with or without a cover-plate,
stayed at ends and by diagonal lacing-bars or
tie-plates; and compression members composed
the form of an I or of two (2) angles in the form
similarly stayed. In any rigid tension member
that has a central web connecting the opposite
lacing may be omitted and replaced by tie-plates.
The end tie-plates shall be placed as close as
of the compression members. For main members
they shall not be less than one-fiftieth (1/50) of the
centre lines of the rivets by which they are connected
the said tie-plates be well stiffened by angles, in
made as thin as three-eighths (3/8) of an inch; and
never be less than their widths, unless they be close
of the member, in which case they may be as short as
For members of the lateral and sway bracing, the
tie-plates shall never be less than one-sixtieth (1/60)
tween the centre lines of the rivets by which they
flanges, and their lengths shall never be less than
their widths. In case the use of intermediate tie or
missible, their thickness shall be the same as that
sponding end tie-plates, and their lengths may be as
that specified for the said end tie-plates, but never less

The lacing of compression members must be
in addition to actual transverse loads, the shear

$$S = \frac{200\,P}{16{,}000 - 60\,\frac{l}{r}};$$

where S = shear on the lacing,
P = total compression on the member,
l = unsupported length of member,
and r = radius of gyration of member,
l and r being taken in a direction parallel to that of

Lacing may be either single or double, the former

[illegible] there is double lattic[illegible] the ends of the member; but for lateral [illegible] may be decreased somewhat. In order to [illegible] for painting, the bars shall be so arranged, and the [illegible] the member shall be such, as to permit of the insertion [illegible] inches in diameter at any point in the system. [illegible] bars may be connected to the flanges by only one rivet at each end [illegible] above specified shall require a greater number; but [illegible] must always be connected by at least two (2) rivets in each end. The axes of adjacent lacing-bars or angles shall preferably intersect on the [illegible] rivets in the flanges of the main member by which they are connected thereto. The bars or angles in double lacing must be riveted at their intersection.

For main members of trusses the thickness of lacing-bars shall never be less than one-fortieth (1/40) of the distance between end rivets for single lacing and one-sixtieth (1/60) thereof for double lacing, measuring [illegible] rivets in case there be more than one rivet in each end. [illegible] of lateral and sway-bracing, the corresponding limits shall [illegible] (1/50) and one-seventy-fifth (1/75). The minimum width [illegible] which a seven-eighths (⅞) inch rivet may be used is to be two [illegible] (2½) inches, and the minimum width of angle leg, three [illegible]. For three-quarter (¾) inch rivets the corresponding limits [illegible] two and one-quarter (2¼) inches and two and one-half (2½) [illegible] smallest section for a lacing-bar shall be two and one-quarter [illegible] by three-eighths (⅜) of an inch, and the smallest section for [illegible] angle, two and one half (2½) inches by two (2) inches by [illegible] (⅜) of an inch.

[illegible] are to be proportioned to resist the greatest shearing and bending [illegible] them by the members which they connect.

[illegible] members composed of four angles in the form of an I with [illegible] line of lacing or tie-plates, the clear distance between backs of [illegible] shall never be made less than three-quarters (¾) of an inch, in [illegible] permit the insertion of a small paint brush.

[illegible] allowable diameter for expansion rollers is six (6) inches; [illegible] must be made segmental. They are to be supported directly [illegible] pedestal, and the detailing must be so designed as to permit [illegible] movement of the rollers in the longitudinal direction of span [illegible] take up the extreme variations in length due to temperature [illegible] live-load chord stresses, and at the same time prevent any [illegible] of the end of the span. The rollers are to be covered [illegible] which makes the enclosed space practically dust-tight; and [illegible] is to be removable so as to permit of the cleaning of [illegible] space. The boxing, however, must not retain water. [illegible] shall be geared to the upper and the lower plates.

[illegible]

[illegible] plates, and [illegible]
[illegible] extreme fibre stress under bending [illegible]
not exceed sixteen thousand (16,000) pounds [illegible]
[illegible] thousand (26,000) pounds for nickel-steel [illegible]
[illegible] thousand (55,000) pounds per square [illegible]
[illegible] for greater elastic limit.
[illegible] Pedestals shall be either of cast steel or built [illegible]
preferably the former. In built pedestals all bearing [illegible]
plates and vertical bearing plates must be planed [illegible]
must be secured to the base by angles having at [illegible]
in the vertical legs; and the said vertical plates [illegible]
end to end upon the base. No base plate, vertical plate [illegible]
shall be less in thickness than three-quarters (¾) of [illegible]
tical plates shall be of sufficient height and must [illegible]
and rivets to distribute properly the loads over the [illegible]
No metal less than three-quarters (¾) of an inch in [illegible]
used in cast-steel pedestals. The bases of all [illegible]
be planed so as to bear properly on the masonry or the [illegible]
and the faces of base plates in contact therewith are [illegible]
so as to furnish perfect contact between rollers and [illegible]
their entire length. All pedestals, whether built or [illegible]
or more diaphragms between webs, carried up as [illegible]
detailing will permit, so as to transmit transverse [illegible]
the base without overstressing the webs by bending [illegible]
direction. Pedestals must not be allowed to hold [illegible]
their boxed spaces are to be filled with rich concrete [illegible]

72. *Details of Design for Riveted-Truss Hig[illegible]*

In general, the rules given for the detailing of [illegible]
spans are to be adhered to in the detailing of riveted [illegible]
with the following possible exceptions:

In cheap highway bridges the lateral diagonals [illegible]
justable rods with right-and-left clevises at their ends [illegible]
to be connected through pins to corner-plates that [illegible]
the lateral strut and the truss member. The unscientific [illegible]
of two or three short pieces of angle iron riveted on [illegible]
plate, and between two of which the rod lies, will not be [illegible]
adjustable rods are employed, the struts to the ends of [illegible]
must be figured for a total compressive stress equal [illegible]
components (in the direction of the said strut) of the [illegible]
working-stresses on all of the adjustable rods meeting [illegible]
strut. While this method gives an excessive stress [illegible]
effect will be a desirable error on the side of safety [illegible]

Where built stringers are used for the floor [illegible]

[illegible] plates, and generally of the economic depth [illegible] [illegible] weight of metal, but never less in depth than one-fifteenth ($\frac{1}{15}$) of the span. Where such stringers are employed, the lower lateral system must invariably consist of rigid sections, each piece being riveted to each stringer where it crosses the same, if practicable.

The smallest section for a lacing-bar shall be one and three-quarters ($1\frac{3}{4}$) inches by five-sixteenths ($\frac{5}{16}$) of an inch, and the smallest section for any lacing-angle $2\frac{1}{2}'' \times 2'' \times \frac{5}{16}''$. No pin is to have a smaller diameter than four (4) inches. The least allowable diameter for expansion rollers is four (4) inches.

73. *Details of Design for Pin-Connected Railway Spans*

The detailing of pin-connected railway spans is to follow in general the specifications previously given for the detailing of riveted-truss railway spans, with the following exceptions:

[illegible] The sections of the top chords and those of the inclined end posts of through-spans shall consist, generally, of two built channels and a cover-plate, each channel being formed of a web and two angles, the upper one small and the lower one much larger, so as to bring the centre of gravity of the entire box section of the member as close as possible to the mid-plane of the web-plates. In no case will more than one cover-plate be allowed, and this is to be made as thin as is proper. It is permissible to substitute rolled channels for the built ones; but when this is done it is [illegible] advisable to rivet a thick narrow plate to the under side of each channel in order to facilitate the packing and detailing of web-members by keeping the centre line of stress as nearly as may be coincident with the [illegible] of the piece.

[illegible] Main vertical posts shall, generally, be composed of two laced channels, [illegible] rolled ones, although built ones must be used where large [illegible] are required. Secondary vertical posts may be built of two [illegible] laced, or of four angles in the form of an I with either a [illegible] of lacing or a web. These secondary vertical posts should, [illegible] be riveted to the top chord instead of being pin-connected [illegible] vertical posts. The channels of vertical posts may have [illegible] turned either inward or outward, as desired, or so as best [illegible] general detailing of the truss.

[illegible] chords and inclined web-struts may be made of either [illegible] with two lines of lacing or four angles with one line of lacing, [illegible] eye-bars for struts being prohibited, as is also the use [illegible]

[illegible] be employed for all bottom chords and main diagonals [illegible] to be stiffened.

[illegible] be used at all pin-holes in built members for the double [illegible] for the metal cut away and of reducing the inten-

[illegible] so as to provide [illegible] these lines. [illegible]

[illegible] the pin ends of compression [illegible] forked ends, for the purpose of packing [illegible] connected by the pin, these jaw-plates [illegible] considered as columns, the thickness of each of [illegible] by the unit stresses previously specified, viz.:

$$p = 10{,}000 - \frac{300\,l}{t} \text{ and } p = \text{[illegible]}$$

[illegible] carbon steel and nickel steel respectively; [illegible] allowable intensity of working stress (impact [illegible] unsupported length in inches, measuring from [illegible] to the centre of the first transverse line of [illegible] which the full section of the member begins, and [illegible] in inches of one jaw. The length l is always to be [illegible] ticable; and, in cases of unavoidably long extension [illegible] stiffened by an interior diaphragm composed of a [illegible] times only two, angles. The greatest allowable [illegible] (20), l being the greatest unsupported length of the [illegible] ways better, whenever practicable, to avoid [illegible] channels; but, if they have to be trimmed, the [illegible] so that the strength of the member will not be [illegible]

Riveted tension members with pin connections [illegible] tion back of the pinhole at least equal to the net [illegible] and a net section through the pinhole at least forty [illegible] than the net section of the member; and there must [illegible] employed to make all the material effective.

Pins are to be proportioned to resist the greatest [illegible] produced in them by the members which they [illegible] have a diameter less than eight-tenths ($\frac{8}{10}$) of the [illegible] bar coupled thereon, nor less than five (5) inches in [illegible]

Lower chords are to be packed as closely as [illegible] manner as to produce the least bending moments [illegible] jacent eye-bars in the same panel must never have [illegible] ($\frac{1}{2}$) inch space between them, in order to facilitate [illegible] ous members attached to any pin must be packed as [illegible] and all interior vacant spaces must be filled with [illegible] omission would permit of motion of any member [illegible] are to lie in planes as nearly as possible parallel to [illegible]

[illegible] are to be made of such dimensions that, when [illegible] to destruction they shall break in the body and not in the eyes [illegible]

[illegible] Details of Design for Pin-Connected Highway Spans

[illegible] In general, the rules given for the detailing of riveted and pin-connected railway spans and riveted highway spans are to be adhered to in the detailing of pin-connected highway spans, with the following possible exceptions:

Counters, when employed, can be of either rounds, squares, or flats. These and all other adjustable members are to have their ends enlarged for the screw-threads, so that the diameter at the bottom of the thread shall be one-eighth (⅛) of an inch greater than that of the body of a round rod of area equal to that of the adjustable piece.

[illegible] pin is to have a less diameter than four (4) inches.

[illegible] of eye-bars are to be made of such dimensions that, when the [illegible] tested to destruction, they shall break in the body and not in [illegible] in the case of loop-eyes, so that they shall not fail in the [illegible] with bent eyes shall not be used. In loop eyes, the distance [illegible] the inner point of the loop to the centre of the pinhole must not [illegible] two and one-half (2½) times the diameter of the pin, and [illegible] must fit closely to the pin throughout its semi-circumference.

[illegible] Details of Design for Railway Trestles and Elevated Railroads

[illegible] and viaducts shall consist of girder spans supported on trestle [illegible] intervals on towers composed of two bents braced together [illegible]. Each bent shall consist of at least two columns, either [illegible] inclined, braced together transversely to the structure.

[illegible] of main members of trestles shall generally be as follows:

[illegible] two channels laced with flanges turned either out or in, two [illegible] channels with I-beam web between, four Z-bars with web-[illegible] with a single line of lacing inside and occasional stay-[illegible] or four angles with a single line of lacing inside.

[illegible] in transverse and longitudinal bracing and all bottom hori-[illegible] struts—four angles with a single line of lacing.

[illegible] transverse bracing struts at top of towers—bracing frames

[illegible] struts at top of towers—plate-girders.

[illegible] girders—plate-girder spans, or occasionally, for very long [illegible]

[illegible] longitudinal girders of trestles and elevated railroads [illegible] between the same shall comply with the specifications

governing the designing of plate-girder spans and the floor systems of riveted spans. In general, the transverse and longitudinal bracing of trestle towers shall consist of a double-cancellation system of stiff diagonals with horizontal struts. The latter at pedestals must be strong enough to move the column feet upon their sliding bearings when the struts are expanded or contracted by changes of temperature. Provision must be made for holding some feet rigidly, and for sliding some in one horizontal direction only and others in any horizontal direction, at the same time holding them all down so that they shall not be lifted perceptibly by the wind pressure. Sliding-plates are nearly always preferable to rollers for pedestals of trestles. They shall be planed extremely smooth, and so as to bear properly at all parts. Occasionally, in solitary bents, it is permissible to use hinged ends for columns at pedestals; but it is generally better to make them fixed, and to figure the columns for the greatest bending produced in them by transverse loads and extreme changes of temperature.

The batter of the columns should, generally, be not less than one and a half (1½) inches to the foot and not more than three (3) inches to the foot. When practicable within these limits, the trestle bent should have such a batter or spread of base as is necessary to meet the condition of no tension on the windward leg—otherwise the tension must be properly provided for.

The tops of trestle columns are to be made vertical by bending them beneath the longitudinal girders where the latter are riveted to them; and the upper transverse struts must be made as deep as the longitudinal girders, and must be riveted effectively to the columns. Corner brackets of double webs are to be used for connecting the columns to the horizontal struts and bracing diagonals, and at the same time to strengthen the column at the bend. Additional strengthening is to be given by using a solid web or diaphragm in the column, extending from the top thereof to a point about two (2) feet below the bend. All splices in columns are to be full, butt splices, located preferably about two (2) feet above the points where the sway diagonals connect, shingle-splicing being avoided because of the trouble it gives during erection. The splice-plates shall be figured to develop sixty (60) per cent of the section of the column; but care must be taken that the maximum bending stresses are fully provided for.

Whenever practicable, the span lengths for trestles are to be those which make the total cost of structure a minimum, the tower length varying from twenty (20) feet for low trestles to forty (40) feet or even more for very high ones, and the intermediate spans varying from thirty (30) to about eighty (80) feet. Any length of girder exceeding eighty (80) feet might necessitate either the employment of a traveller that would be too long, heavy, and expensive, or the use of bents of falsework between the towers.

For elevated railroads the sections of main members shall be as follows:

Longitudinal girders—preferably plate-girders, or, if necessary, open-webbed, riveted girders.

Cross-girders—plate-girders.

Columns for structures without longitudinal or tower bracing—two rolled or built channels with an I-beam riveted between.

Columns for structures with longitudinal or tower bracing—four Z-bars with a web-plate.

All columns for elevated railroads are to have both ends fixed, being held rigidly at the top by either the longitudinal girders or by deep struts that carry the thrust of braked trains from the track to the columns, and their sectional areas are to be figured accordingly for both direct load and bending.

Longitudinal girders in elevated railroads shall, generally, be riveted into the cross-girders and not rest thereon, except under certain conditions for the sake of clearance beneath, in which case the top flanges of the half-through girders must be stayed at the ends and at intermediate points, as specified for plate-girder spans. On all curves in elevated railroads, special lateral bracing of angles, riveted at intersections to the longitudinal girders and carried over and riveted to the columns, must be employed. Shelf angles for facilitating erection are to be provided on columns for the temporary support of the girders and in any other places where their use would expedite the work.

In general, the limiting length of structure between expansion points shall be about one hundred and fifty (150) feet. If this length be exceeded materially, the columns may have to be strengthened to resist the bending caused by changes in temperature.

All expansion-pockets are to be so detailed as to throw the load from the longitudinal girder as close as possible to the web of the cross-girder; and sufficient rivets are to be used in connecting the pocket to the cross-girder or column to provide for both the direct shear and the bending moment from the eccentric load; and the cross-girder or column is to be thoroughly riveted to the adjoining longitudinal girder so as to care properly for the bending or to avoid torsion.

All anchor bolts at column feet are to extend well up above the base-plate, passing between two angles that are riveted to the column, and which support a heavy washer-plate or angle to receive the anchor-bolt nut. All column feet are to be raised so far above the ground that no dirt, snow, nor moisture can collect around them and remain there. The boxed spaces at column feet are to be filled with Portland cement concrete made with small broken stone.

The bases of pedestals are always to be made large enough to prevent all possibility of settlement of foundations. In figuring the pressure on the base of the pedestals it is not sufficient to recognize only the direct

76. *Details of Design for Highway*

The specifications for the "Details of Design for [illegible] Railroads," and those for the "Details of [illegible] Spans" are in general to be followed in the designing of highway viaducts, the principal [illegible] structures, adjustable rods with clevises [illegible] diagonals in the four faces of the braced towers, be riveted to the columns by means of wide plates [illegible], and must never be pin-connected.

The detailing for the longitudinal girders of viaducts between the same shall comply with the specifications for plate- or open-webbed riveted-girder spans; and the wooden floor system, paving, hand-rails, etc., shall be the way viaducts as for highway bridges.

77. *Swing Spans*

The following types of structure are to be used for

For spans up to two hundred (200) feet in length—pl acting as continuous girders over the pivot pier.

For spans between two hundred (200) feet and four —riveted truss bridges.

For spans exceeding four hundred (400) feet—either connected bridges.

For spans up to about three hundred (300) feet it is top chords horizontal throughout, and beyond that length them polygonal or to provide a tower at mid-span.

It is understood that these limiting lengths are not as the best limits will vary somewhat with the number of weight of trains.

For highway swing spans the following types of employed:

For spans up to one hundred and fifty (150) feet girder spans, acting as continuous girders over the pivot-

For spans between one hundred and fifty (150) (300) feet, riveted trusses are to be used.

For spans of over three hundred (300) feet, either connected trusses with subdivided panels may be adopted

It is understood that these limiting lengths are as the best limits will vary somewhat with the wid live load to be carried.

Swing spans may be either rim-bearing or centre-

[illegible] and one-seventh (1/7) of the total length of span, measuring from centres to centres of end-pins, although in certain cases it may, for the sake of appearance, be made a little greater. The truss depth at the inner hips should be from one-ninth (1/9) to one-tenth (1/10) of the total length of span. The truss depth at outer hips for spans up to four hundred (400) feet will generally be determined by the clearance required. For longer spans it should be between one-fourteenth (1/14) and one-fifteenth (1/15) of the total span-length. The least allowable perpendicular distance between central planes of trusses shall be one-twenty-fifth (1/25) of the total length of span.

The length of the centre panel in rim-bearing draws will, in most cases, be made equal to the perpendicular distance between central planes of trusses. In spans having horizontal top chords, all panels of the latter must be composed of stiff members, except the two central panels in pin-connected trusses. Broken top chords must be made of stiff members from ends to inner hips, but the portion between the inner hips may be of eye-bars. Inclined posts extending from the inner hips to the drum are to be used in all cases where the top chords are broken and where the structure is rim-bearing.

The loads to be considered in designing swing spans are the following:

(A) Live Load.
(B) Impact Due to Live Load.
(C) Dead Load.
(D) Impact Due to Dead Load.
(E) Uplift at Ends.
(F) Direct Wind Load.
(G) Indirect Wind Load or Transferred Load.
(H) Unbalanced Wind Load on One Arm only.
(I) Vibration Load.

Live Load.

The live load for trusses with only one arm loaded is to be taken from the equivalent-load curves for a span equal to the distance between the centre of the end-pin and the centre of the nearer tower post; but for both arms loaded the live load is to be taken for a span equal to the distance between centres of end-pins. For only one arm loaded, the half-span is to be considered to act as a simple span on two supports; and for both arms loaded, the entire span is to be considered continuous over four supports for a rim-bearing draw and over three supports for a centre-bearing draw. The stresses due to the live load, with both arms wholly or partially loaded, are to be determined by the balanced-load method. [illegible] in determining the reactions at ends and at centre supports, [illegible] shown in Fig. 29a can be used for rim-bearing spans and [illegible] for centre-bearing spans. The former gives, for balanced [illegible] portion of the load in one arm that is supported at its outer

arm, while the latter gives the reactions at the
of unity placed anywhere in either arm.

In spans of over three hundred (300) feet, the
is to be increased properly from the ends toward the
order to cover the weight of the heavy truss-members
middle toward the centre of the span. The dead loads
and turntable are not to be considered as affecting the
trusses.

The impact due to dead load is to be taken as
cent of the said dead load.

The wind loads per lineal foot of span for both the
unloaded chords when the draw is closed are to be the
specified for fixed spans, and only one-half as great
open, the length of span used, however, being that of one
They are to be taken from the curves in Figs. 29
span is open, all the wind load is to be carried to the
lateral systems. When the draw is closed, the wind load
to both the ends and the centre supports. In case a
the adjacent chords be considered to act as a continuous
centre supports, the reactions at the ends and at the
from the curves in Figs. 29*a* and 29*b*.

In the case of trusses with broken top chords, the wind
chords is to be assumed to travel through the upper
inner hips when the span is open, then down the inner
drum, thus producing a transferred load on the leeward
a released load on the windward one. As the upper
to be made continuous between the inner hips, none
on the upper lateral system will be carried down the
ing only that which comes on the centre panel and the
In order to ensure such a distribution of the wind load,
not be put in those panels of the upper lateral system
to the inner hips and between these and the tower.
chords between the hips from both the direct and the
load shall be duly figured.

In the case of trusses with parallel chords, the wind
chords is to be assumed to travel through the upper
the tower posts when the span is open, then down the
drum, thus producing a transferred load on the leeward
a released load on the windward one.

When the draw is closed, for trusses with either
or parallel chords, one-half of the wind load on the
of one arm is to be assumed to travel down the
and one-half down the inner inclined posts
the case may be—the proper transferred and
figured in all cases. A vertical unbalanced wind

[illegible] per square foot shall be assumed as acting upward on the entire bottom area of one arm only when the span is swinging, the exact amount depending on the relative exposure of the structure to high wind pressures; and the span must be so anchored as to care properly for this load.

The vibration load, which applies to railway spans only, is to be as specified in clause 44.

In ascertaining the stresses in the trusses of swing-bridges the following conditions are to be considered:

Case No. 1. Greatest stresses, dead load only acting, bridge open.

Case No. 2. Greatest stresses, dead-load impact only acting, bridge open.

Case No. 3. Greatest stresses from assumed uplift at end of span.

Case No. 4. Greatest stresses from live load on one arm only; each arm being considered to act as a simple span on two supports, the usual allowance for impact being made.

Case No. 5. Greatest stresses from live load on both arms, the live load advancing from both ends toward the centre until the span is fully loaded, the latter being considered to act as a continuous girder over four supports for a rim-bearing span and over three supports for a centre-bearing span.

Case No. 6. Greatest direct stresses, on the chords that carry the live load, from wind load when the bridge is open.

Case No. 7. Greatest direct stresses, on the chords that carry the live load, from wind load when the bridge is closed and wholly or partially loaded.

Case No. 8. Greatest indirect wind-load stresses or transferred-load stresses on the lower chords when the bridge is closed and wholly or partially loaded.

[illegible] combination of these stresses includes Cases No. 1 and No. 2; [illegible] the greatest stresses for all truss members from dead load and [illegible] impact, when the span is swinging. The second combination [illegible] No. 1, No. 3, No. 4, and No. 5, and gives the greatest stresses [illegible] live and dead loads. It is to be noted that, as previously [illegible] wherever the load for Case No. 3 increases the total stress [illegible] member, its effect is to be considered; but wherever the said load [illegible] total stress on any member, its effect is to be ignored. The [illegible] intensities of unit stresses are to be used for both the [illegible] combinations.

[illegible] combination of these stresses includes Cases No. 1, No. 2 [illegible] gives the maximum stresses, including wind, when the [illegible] The fourth combination includes Cases No. 1, No. 3, No. 4, [illegible] No. 8, and gives the maximum stresses, including wind, [illegible] closed. For the third and fourth combinations, the [illegible] thirty (30) per cent higher than for the first and [illegible] It should be noticed, however, that the only truss

[illegible] of through-[illegible]
[illegible]

Case No. 1. Greatest wind-load stresses when [illegible]

Case No. 2. Greatest wind-load stresses when [illegible] raised, thus making the upper lateral system of [illegible] top chord a simple span, and making the entire lower [illegible] the bottom chords a continuous girder over four points [illegible] bearing span, and over three points of support [illegible] span. This case does not involve the presence of any live

Case No. 3. Greatest vibration load stresses [illegible] those in Case No. 2.

For lower lateral systems of through-bridges and [illegible] tems of deck-bridges.

Case No. 4. Greatest wind-load stresses when span

Case No. 5. Greatest wind-load stresses when span [illegible] are raised, and with live load on one arm only, thus [illegible] chords with their lateral system a simple span with supp

Case No. 6. Greatest wind-load stresses when span [illegible] are raised, and with the live load on both arms covering [illegible] or partially, thus making the loaded chords with their [illegible] continuous girder with four (4) points of support in the [illegible] bearing span and with three (3) points of support in the [illegible] bearing span.

Case No. 7. Greatest vibration load stresses under [illegible] those in case No. 5.

Case No. 8. Greatest vibration load stresses under [illegible] those in Case No. 6.

The greatest stress on any lateral member found by [illegible] tions of wind-loading is to be used in proportioning its [illegible] is to be assumed no division of the wind load between [illegible] although the failure to make the said division will cause [illegible] the side of safety.

78. *Special Details of Design for Plate-Girder Swing*

Plate-girder swing-bridges are to be made as continuous [illegible] three or four points of support—preferably over three. [illegible] either rim-bearing or centre-bearing. The same combin[illegible] are to be used as specified for truss draw-spans, but it [illegible] found that the wind loads do not affect the proportion[illegible] In general, the specifications for the detailing of fixed [illegible] are to govern the designing of plate-girder draw-spans, [illegible] after stated.

In deck, plate-girder draw-spans the girders are to be spaced the same distance apart as specified for fixed plate-girder spans of one-half the length. For half-through, plate-girder draw-spans the girders may be spaced as closely as the previously specified clearance requirements will permit. For deck-spans four points of support on the drum will suffice, but for half-through spans eight points will be required. The diameter of the drum is to be made as small as practicable, but never less than eight (8) feet; and the distribution of the load over the drum is to be uniform. All girders are to be thoroughly stiffened at all points of bearing over the drum, and bearing-plates not less than one (1) inch in thickness are to be used between the drum and all girders bearing thereon.

When the length of span over all exceeds one hundred (100) feet, it will be necessary to splice the main girders in the field. These splices must be thoroughly made, shingle or staggered splices only being allowed; and there must be ten (10) per cent excess of strength in the details at all points thus spliced, as previously specified for fixed plate-girder spans.

Rigid bracing-frames are to be used between main girders of deck-spans at the points where the main girders bear on the drum; and heavy, rigid, plate cross-girders resting on the drum are to be used for half-through spans.

79. *Special Details of Design for Trusses of Swing Spans*

The details of trusses for swing-spans shall comply in general with the specifications given for trusses of fixed spans. In pin-connected trusses having broken top chords, that portion of the said chords between outer and inner hips is to be made of rigid members, and that portion between the inner hips and over the tower is to be made of eye-bars. In pin-connected trusses with parallel chords, rigid members will be required throughout the top chord, except for the centre panel, in which eye-bars may be used. In riveted trusses stiff top chords from end to end of span are to be adopted. Ample provision for adjustment of elevations of ends of span shall be made by means of shimming plates of various thicknesses at each end-bearing.

Rigid portal-bracing attached to both the upper and the lower flanges must be used between the two inclined posts at both the inner and the outer hips. These portals are to be carried down as low as the specified clearance over tracks will permit.

The tower must be rigidly braced in all four faces. In the transverse planes all the diagonals and horizontal struts must, generally, be made of stiff members of box or I-section, so as to take hold of the exterior of the posts; and this sway-bracing must be carried down as low as the specified clearance will permit, in order to hold the tower posts firmly to place and line. In the planes of the trusses the diagonals are to be made of stiff members having ample section to provide for any possible unequal

[illegible] when the span is
are to be of bar or I-section. A pair of rigid
horizontal plane of each vertical panel of tower
the permanent rectangularity of the section of the
The upper lateral system between the inner and the
the tower panel is to be made of rigid diagonals,
tension and compression, and transverse struts of
curely riveted to both the upper and the lower flanges
The transverse sway-bracing between trusses is to
of rigid members, and is to be carried down as low as
ments will permit. In long spans the lower horizontal
tical sway-bracing must take hold of the vertical posts
same so as to hold the said posts firmly in position.

80. *Camber and Deflection of Swing*

The lengths of all truss members shall be such that
uplift is applied by the wedges at the ends of the
greatest live load is on the structure, the centre lines
from end to end of span will lie in a horizontal plane.
ment of the ends from the condition of no stress in the
weight of the finished span is supported on the falsework,
of the span swung, must be very carefully figured, as
the camber increments or decrements in lengths of
ances, the adjustments, etc. Due allowance shall be
chord's having a temperature 30 degrees F. greater than

81. *Details of Drum and Loading Girders for Rim-Bearing*

The drum must be strong and deep enough to
load from the span properly over the rollers. In
made, within reasonable limits, as deep as possible,
one-half of the greatest distance between adjacent points
the cost due to the extra depth will be more than
in height of pivot-pier. The bending moment on the
puted by the compromise formula,

$$M = \frac{1}{10} W.l;$$

where M = bending moment in foot-pounds, W = greatest
on one point of bearing on drum, and l = distance in feet
of bearing. The drum is to be designed according to
for ordinary plate-girders. The web thereof shall have
sides at all points of concentration. These stiffeners
contact with the top and bottom flanges. The section
stiffeners is to be determined by considering the entire
one point of bearing to be carried by the said stiffeners

column, fixed at both ends, with an unsupported length equal to the depth of drum. The bearing area of the outstanding legs must also be adequate for the load carried. Stiffeners, each consisting of two angles, placed on opposite sides of the web, must be used at intermediate points at distances not exceeding either the depth of web, or three (3) feet six (6) inches. Fillers are to be used beneath all stiffeners.

Brackets to support the pinions gearing into the rack are to be provided on the drum and are to be securely riveted thereto. They shall be built of rolled-steel sections, and made amply strong in all directions and in every particular so as to resist the greatest thrust, wrenching, or torsion that can possibly come from the shaft. In no case are such brackets to be made of castings. The use of turned bolts for attaching the brackets to the drum will not be permitted where it is possible to drive rivets, as such bolts do not afford sufficient rigidity to prevent the connections from working loose sooner or later.

The splices in the web and flanges of drum must be such as to develop the full strength of same; and the abutting ends of web and flanges must be planed smooth so as to have continuous contact. The drum must be made perfectly round, so that the centre line of web at any height will conform to the circumference of a circle; and to preserve this form and brace the drum thoroughly, rigid radial struts are to be run from the centre casting to the drum, taking hold of the latter at each point of concentrated loading and at intermediate points when the bearings are spaced more than eight (8) feet between centres. These radial struts must be made of four angles with solid webs or angle-lacing. At the centre they are to be riveted to circular plates fitting closely around the centre casting, thus anchoring the drum firmly to the latter. Oil-grooves must be provided where these plates bear on the centre casting.

The drum must be assembled and the bottom must then be planed smooth so as to provide an even bearing for the upper track. If it is not practical to plane the entire drum at once, then each segment thereof is to be planed separately; but in this case the greatest care is to be taken to make the assembled parts form a perfect whole. The least thickness of metal to be used for bottom flanges of drum shall be three-quarters (¾) of an inch for railway spans and five-eighths (⅝) of an inch for highway spans, so as to provide ample metal for planing off the bottom; and that for the web and top flanges, one-half (½) inch for railway spans and three-eighths (⅜) inch for highway spans.

Spans resting on drums of small diameter in proportion to the span length are to be anchored to the pivot-pier by means of a large anchor-rod in centre of pier, extending down ten (10) or fifteen (15) feet into same. This rod shall pass through the centre casting and through a box-girder over the centre of the drum, which girder shall rivet into either the transverse or the longitudinal girders. The lower end of the rod shall pass through a heavy cast-iron anchor-piece embedded in the con-

[illegible] shall be proportioned [illegible]
[illegible]
[illegible] girders over the drum shall be [illegible]
[illegible] it properly. The number of bearing [illegible]
[illegible] the length of span, the distance [illegible]
[illegible] load to be carried, and the economical [illegible]
[illegible] of the supporting girders in turn [illegible]
of bearing points to be used. For ordinary, [illegible]
up to three hundred (300) feet in length a very [illegible]
girders over drum is secured by making the [illegible]
the length of centre panel equal to the [illegible]
[illegible]; then the middle points of both the [illegible]
[illegible] girders will be directly over the web of the [illegible]
four points of bearing. Four more points are [illegible]
diagonal girders, which connect to both the [illegible]
[illegible] girders and bear on the drum at their [illegible]
gives in all eight (8) points of support. The [illegible]
diagonal girders over the drum shall be so designed [illegible]
will be such that when deflected under the load the [illegible]
will be about the same in all the said girders. (8) [illegible]

The bottom-chord stresses in the centre panel [illegible]
longitudinal girders, or the bottom-chord sections can [illegible]
the centre panel, the longitudinal girders being [illegible]
steel chairs being inserted beneath their centres to [illegible]
the drum. In case the bottom-chord stresses are [illegible]
tudinal girders, ample provision must be made for [illegible]
the bending stresses, in designing the sections for [illegible]
the clearance over the waterway will permit, metal [illegible]
ting the top flange of the longitudinal girder form the [illegible]
the truss.

In single-track spans of three hundred (300) feet or over, [illegible]
track spans of two hundred (200) feet or over, cast-[illegible]
bearing-blocks are to be used between the top flange of [illegible]
bottom flanges of the girders, in order to make definite [illegible]
centration, and so as to transmit the load properly [illegible]
For smaller spans, bearing-plates, at least one (1) inch [illegible]
structures and three-quarters (¾) of an inch thick for [illegible]
may be substituted for the ball-and-socket blocks.

All girders bearing on the drum are to have [illegible]
of their webs at all points of concentration; and in [illegible]
feners to be crimped, but are to have fillers [illegible]

close bearings at top and bottom flanges; and they are to be proportioned in the same manner as previously specified for those on the drum.

82. *Supporting Girders for Centre-Bearing Swing Spans*

In centre-bearing draws the dead load shall generally be carried by a system of girders supported on top of the centre casting. Four rolled or built-up beams running transversely to the axis of the bridge shall be supported directly on and securely bolted to the upper part of the centre casting. Suspended from these beams shall be two pairs of beams, one on each side of the centre casting, parallel to the axis of the bridge and riveted to two cross-girders, one on either side of the centre casting placed as close together as practicable. All beams shall be designed particularly for rigidity so that the amount of deflection in them will be inappreciable. The suspenders shall generally consist of four (4) rods with nuts at each end. In small spans when there is sufficient clearance, the cross-girders may be supported directly on the centre casting, or the supporting beams may be run longitudinally and riveted directly to the cross-girders. But, as a rule, the suspended system is preferable on account of the possibility of adjustment.

The live load shall be carried on wedges at the centre of the span and shall be transferred to the said wedges by longitudinal beams riveted to the cross-girders.

The span shall be supported during rotation by six or eight trailing wheels in bearings attached to the trusses at the sides and to special structural frames at intermediate points. All parts must be designed for the wind loads on them due to the tendency of the span to overturn about its centre.

The top of the pivot-pier is to be levelled off with neat Portland-cement mortar, and the lower track is to be set in same. It shall be made one and one-half (1½) or two (2) inches higher in the centre than at the edge, so that the water will drain toward the latter. A small gutter or depression in the top of the pier is to be made just inside of the lower track, and at the bottom of this depression drain-holes are to be put in, leading the water from the gutter down on the outside of the pier. These drain-holes are to be at least three (3) inches in diameter, and the tops are to be protected with screens, so as to prevent choking. They are to be spaced not to exceed ten (10) feet between centres.

83. *Lift Spans*

In general, the preceding specifications for fixed and swing spans shall govern the design of lift spans. The following special points shall, however, be considered.

The operating machinery and the machinery-house shall be placed at the centre of the span. In truss spans the house shall be located

above the top chords, or between the trusses
truss depth is sufficient to permit this construction
the machinery shall generally be placed between the
deck. In half-through plate-girder spans, the machinery
either below the deck or outside of the girders. The
house shall be supported on steel beams and girders
trusses or main girders.

The suspending cables shall be connected either to the
ders direct, or to lifting girders between the trusses or
spans the lifting girders shall be framed into the
U_2 points, and shall generally consist of two leaves
proper connections for the ropes. In deck, plate-girder
girders shall be framed between the main girders at the
extend beyond the said girders on each side for the rope

Each tower for a short plate-girder span with a low
of two single columns with transverse sway bracing,
tudinal overhead bracing between the two towers. For
longer spans the overhead bracing shall be omitted, and
columns shall be braced by back-legs attached to the
to masonry. These back-legs shall be sway-braced
braced to the main columns longitudinally.

At the top of the tower the main tower columns
by the sheave-girder. This girder shall consist of either
depending on the weight to be lifted and the make-up
section. Where the column is composed of four
either with or without side-plates, a single-leaf girder
used; and where it consists of rolled or built
turned in and connected by a diaphragm of four
a double-leaf girder shall be adopted. The back-
together at the top by a shallow, single-leaf girder
be employed between the main tower columns and
zontal bracing shall be used between these girders.

As a rule skew crossings shall be avoided; but
and a large skew exists, and where the towers are
on masonry, they shall be built up of four vertical
four vertical planes and in the top horizontal plane.

Where the towers consist of two columns braced
the sheaves shall generally be supported on the tower
and on subposts supported on top of the sheave-
webbed girders are adopted, or riveted between the
webbed girders are employed. In the former case
braced to the transverse girder between the back-
consists of two columns alone or of four columns
tower sheaves shall be supported on subposts
In ordinary towers only two sheaves shall

[illegible] shall move up and down inside of the towers. In slow [illegible] [illegible] openings in which the tower consists of four main columns, four [illegible] shall be employed, and the counterweights shall move up and down outside of the tower.

Rigid supports and connections shall be provided for all machinery parts.

84. *Bascule Spans*

Bascule spans shall, in general, conform to the preceding specifications for fixed and movable spans, and each type will have its own peculiar details to be worked out.

In highway bascule spans the floor construction shall be such that there will be no displacement of the floor when the span is in its raised position. This will generally require the use of a timber plank floor.

All parts of the moving span shall be designed for the stresses produced for any position of the span from the fully-open to the closed. Where the stresses are indeterminate as is the case in the counterweight [illegible] of certain trunnion bascule spans, each member shall be figured for the greatest possible stress that may come on it under the most logical [illegible]. Such members shall, preferably, have a section somewhat [illegible] of that required by theory.

[illegible] for trunnion bascules shall be made as rigid as practicable so [illegible] their deflections to the greatest extent possible. Proper [illegible] shall be made at the points of support, as well as at the bearing [illegible] the trusses, for the deflection of the axle.

[illegible] double-leaf bascules for highway bridges a substantial connection [illegible] provided between the ends of the two leaves.

85. *Structural Supports for Machinery*

[illegible] supports and connections for machinery shall be prop[illegible] for the loads carried as well as for all stresses induced by [illegible] of the machinery; and an impact of one hundred (100) [illegible] be applied to the latter. The beams in the machinery-[illegible] figured to support a load of 5,000 pounds, or the heaviest [illegible] in the house, in addition to the load from the floor [illegible] itself. The unit stresses employed shall be one-half (½) [illegible] specified for ordinary structural work.

POWER

86. *General*

[illegible] movable span, either hand power or some kind of me[illegible] be employed, the determination of this point de[illegible] local conditions. Wherever the operation is very [illegible] ample time for opening is available, hand power may

[illegible]

machinery in good working condition. Where [illegible] mechanical power in the future, provision [illegible] installation of such equipment.

In most cases it will be found advisable to employ some mechanical power; and, as a rule, either an electric or [illegible] motor will prove the most satisfactory. Whenever [illegible] electric current, the electric motor should be adopted [illegible] ternal combustion motor. As a source of power, [illegible] rather unsatisfactory; and, unless called for by special [illegible] they should be avoided. In all cases ample power shall be [illegible] emergency equipment installed. In certain cases hand [illegible] satisfactory for the emergency equipment; but where [illegible] that it is impracticable, a gasoline engine shall be used. [illegible] must also be employed to stop and hold the span in any [illegible] all conditions governing its operation.

In operating the span, the power equipment must be [illegible] come all resistances in the times specified for opening [illegible] ditions. The forces to be overcome are friction, inertia, [illegible] wind, and in some cases certain unbalanced loads. [illegible] shall be taken the same as is used in the designing of the [illegible] In locations where snow is likely to occur during the [illegible] season, proper provision must be made for taking [illegible] design of power and machinery equipment.

For railway floors the area exposed to wind shall be [illegible] five (85) per cent of the gross area.

For spans where unusual wind conditions exist, [illegible] must be given to the design of the operating equipment [illegible]

In determining the power required for all types [illegible] well as in designing the machinery, the efficiency of a [illegible] shall be taken at ninety-three (93) per cent. This [illegible] friction. The efficiency of a set of bevel gears shall be [illegible] five (85) per cent., and of worm-gearing at fifty [illegible] per cent.

The torque at the armature shaft required to [illegible] throughout the movement of the span shall be [illegible] by curves, together with a curve showing the total [illegible] at any time during the operation of the span.

87. *Swing Spans*

For centre-bearing swing spans the friction shall [illegible] per cent of the total load on the pivot; and for [illegible] tenths (.6) per cent of the load on the rollers. [illegible]

[illegible] of the rollers in [illegible] [illegible] of the disc from the [illegible] centre-bearing drawspans. Applied at the pitch line of the rack the force becomes

$$F_1 = \frac{.06\,WR_1}{R} \text{ for centre-bearing swings,}$$

$$\text{and } F_2 = \frac{.0006\,WR_2}{R} \text{ for rim-bearing swings;}$$

where R_1 = radius of disc for centre-bearing swings,
R_2 = radius to centre of rollers for rim-bearing swings,
R = radius of pitch-line of rack,
and W = weight on rollers or disc.

The force at the rack to overcome inertia is

$$F_3 = \frac{M\alpha r^2}{R^2};$$

where M = Total mass to be moved,
α = Lineal acceleration at pitch circle of rack,
r = Radius of gyration,
and R = Radius of rack.

[illegible] swing spans opening in from one (1) to one and one-half (1½) minutes, the period of acceleration should be taken at from ten (10) to twenty (20) seconds, and the period of retardation from ten (10) to fifteen (15) seconds.

For greater times of opening these periods should be increased in about the same proportion.

Generally r^2 can be assumed equal to $\frac{a^2+b^2}{3}$,

where a and b are the half-length and half-width of the span. Where [illegible] is very long and there is considerable variation in the weight of [illegible] per lineal foot, the total weight at each panel-point should be [illegible] the radius of gyration, r, determined by assuming these weights [illegible] at the centre line of truss.

Assuming $r^2 = \frac{a^2+b^2}{3}$, and $M = \frac{W}{32.2}$ (where W is the weight corre[illegible] to the mass M), the force at the rack to overcome inertia becomes

$$F_2 = \frac{W\alpha\,(a^2+b^2)}{96.6\,R^2}.$$

[illegible] wind load of one (1) pound per square foot shall be [illegible] on the exposed area of one arm of the span as seen in [illegible]. The centre of this load shall be taken at a distance

of $l/3$ from the axis of rotation, where
span. The force at the rack to overcome
[illegible]

$$F_3 = \frac{Pl}{2R},$$

where P is the total unbalanced wind load on one arm
be added to those for friction and inertia; and the power
be capable of overcoming all these forces in the
or the least time specified for opening. In the
this time should usually vary from one (1) to one and
minutes. Where the conditions so warrant, this limit
according to the judgment of the Engineer. The
be strong enough to hold the span against an
ten (10) pounds per square foot. Special cases
one arm will be protected from the wind while the other
arm may be longer than the other, as in a bob-tailed draw
will have to be given special consideration when they arise.

In operating the end and centre wedges, the forces
the horizontal components of the vertical reactions
the friction on each contact surface. This friction
teen (15) per cent for each surface. In case toggles
ends of the span, the friction in the toggle-joints
fifteen (15) per cent of the total load thereon. For
a proper allowance of power is to be made. The wedges
be opened or closed in from fifteen (15) to thirty (30)

88. *Lift Spans*

For vertical lift spans the friction on the journal
twelve (12) per cent at the start and reduced by
in speed of one (1) foot per minute at periphery of journal
tion has been reduced to six (6) per cent. This force
to an equivalent force at the rim of the tower sheave.
of the journal, R = the radius of the supporting sheave
ing load, the force in the operating ropes to overcome
becomes

$$F_1 = \frac{0.12\,Wr}{R}.$$

The force at any other instant shall be determined
using the proper friction factor.

The force necessary to overcome inertia is

$$F_2 = M\alpha = \frac{W\alpha}{32.2},$$

where W = total moving load, and α = the

spans opening in from one (1) to one and one-half (1½) minutes, the acceleration should take place in from ten (10) to twenty (20) seconds and the retardation in from ten (10) to fifteen (15) seconds. Where the time allowed for opening and closing is greater, the period of acceleration and retardation should be increased correspondingly. In lifting-decks, the time for opening should vary from one-half (½) to one (1) minute, and the time of acceleration should be decreased in due proportion.

Except when the span and the counterweight are at mid-height of lift, the counterweight ropes themselves are unbalanced. This condition may be overcome by special balancing chains; but when this is not done, the weight of the unbalanced rope must be taken care of by the operating equipment. The force necessary to overcome the effect of the unbalanced cables is

$$F_3 = R,$$

where R is the weight of the unbalanced cables at any point in the travel of the span. It must be remembered that for the first half of the operation in either direction this unbalanced load acts against the force tending to move the span, whereas in the latter half thereof it acts with that force and against the braking action.

For normal operation a wind load of two (2) pounds per square foot shall be assumed as acting against the exposed area of the span as it is seen in vertical projection. The friction on the guides due to this wind load must be overcome by the operating ropes. This friction shall be taken as fifteen (15) per cent of the said wind load.

For normal operation of from one (1) to one and one-half (1½) minutes the operating equipment must be capable of overcoming the above forces. It must also be capable of moving the span for all wind loads of less than fifteen (15) pounds per square foot, although the time of operation under such a condition shall be increased accordingly.

The span-locks for lift bridges shall, as a rule, be operated by hand, when the operator is located in the machinery-house. However, when mechanical operation is required therefor, it shall be designed to meet the case in hand.

89. *Bascule Spans*

For bascule bridges the power equipment will depend on the type of bascule used; and, in general, it will be governed by the preceding specifications for lift bridges. For rolling bascules the coefficient of rolling friction shall be taken at eight (8) per cent. The operating equipment on all types must be capable of holding the span in any position for a wind load of fifteen (15) pounds per square foot on the exposed surface as seen in vertical projection, and of moving it in the specified time against a wind load of two (2) pounds per square foot thereon.

[illegible] hand power is used on the [illegible] to operate shall be [illegible] exert a force of 40 pounds on a lever [illegible] corresponding about one-fifth of a [illegible] strength of the machinery a man shall be [illegible] force of [illegible] pounds.

91. *Electric Operation.*

The motors for performing the various [illegible] and close the movable span shall be of either A. C. [illegible] or D. C. (direct current) construction, depending [illegible] available at the bridge site. For alternating [illegible] type slip-ring induction, or railway motors [illegible] current, railway, crane, or mill type [illegible] drum armatures and form-wound armature [illegible] weatherproof or protected by weatherproof [illegible] permit easy access for inspection and repairs. [illegible] tapped for conduits so as to avoid exposing [illegible] commercial motors in common use shall be [illegible] parts can be readily obtained. Motors entirely [illegible] vided with openings for inspecting commutator [illegible] shall either have the armature shaft extended and [illegible] ling, or shall be provided with back gears. In the [illegible] steel pinion shall be keyed and locked to the [illegible] engage a cast-steel gear keyed to a secondary [illegible] motor frame. The secondary shaft shall be [illegible] and the back gearing shall be properly housed. [illegible] machine-cut teeth.

For light spans one motor shall generally be [illegible] span; but for heavy spans two motors, although [illegible] be used, if the engineer so decides. Where two [illegible] operate the span in the normal time, provision shall [illegible] it in a longer time with one of the motors alone. [illegible] the two motors shall be operated in series [illegible] shall be used to raise the ends of swing spans, [illegible] and gates where mechanical power is used there[illegible] be capable of developing the necessary torque [illegible] for performing the various operations within the [illegible] shall be rated on the one-half (½) hour basis, [illegible] Rules of the A. I. E. E., viz.:

After one-half hour's run at the rated load [illegible]

part of the motor windings shall not exceed by more than fifty (50) degrees C. that of the surrounding air, if the temperature of the surrounding air is twenty-five (25) degrees C. The permissible rise in temperature shall be increased or decreased one-half of one per cent for each degree centigrade that the surrounding air is less than or greater than twenty-five (25) degrees C. The normal running and starting torques and the maximum running and starting torques of the motors shall be obtained from the company or companies manufacturing the motors selected. For normal operation, the sum of the normal starting torques of the motors shall be slightly in excess of the starting torque needed to move the span, and the sum of the normal running torques at maximum speed required shall be slightly in excess of the running torque required at the end of the accelerating period. Where two motors operate the span, the maximum starting and running torques of each motor shall be well in excess of the total starting and running torques required. Under all conditions of operation there shall be no injurious heating or sparking of the motors. The speed of the motors throughout the operations shall be such as to open or close the span in the required time.

All motors shall be equipped with standard solenoid brakes with a braking torque that will stop operation in the required time. These brakes shall be set by springs or other mechanical means, and released by solenoids operating only when the motors are drawing current, except as hereinafter provided. The solenoids shall have ample capacity for all currents passing through the motors without exhibiting injurious heating. The friction surfaces shall be of materials not affected by moisture. To make coasting possible, a release shall be provided for each solenoid brake, allowing it to draw current when the motors are shut off at the will of the operator. Weatherproof motors shall be provided with weatherproof solenoids.

Motors shall be mounted so as to afford easy access for inspection and repairs. They shall be supported on good, substantial brackets or foundations. For each size of motor there shall be furnished the following extra parts: one armature, one set of field coils, one set of brushes, and one pinion and one split gear (if the latter two are supplied with the motor) fitted and ready for quick installation.

Controllers shall be of the reversing-drum type with contacts protected by blowout magnets, except where the currents are too large for the ordinary controller or where remote control is necessary, in which cases there shall be magnetic switches on the switchboard operated by master controllers. All controllers shall be of ample carrying capacity to operate the motors under all conditions without injurious sparking. They shall be capable of varying and maintaining the speed from zero at the start to the maximum running speed without injurious sparking or shock due to sudden variation in speed. Sufficient steps shall be provided on the controller so that the torque of the motor will vary approximately

of the torque required. The controllers and brake will be released on the first notch the second. Where two D. C. motors are used, by one series parallel type controller, capable of or either motor alone. Separate controllers shall be lifting, locking, or gate motors where electrical All apparatus shall be so interlocked that all operations only in their proper sequence. In railway bridges, shall be provided so as to release the various motors in case the interlocking system becomes deranged or sufficient time to set the signals without great risk of the span. These switches shall be placed in sealed switchboard.

Cast grid resistances shall be used in the motor as to carry the currents required without destruction; shall be properly mounted so as to avoid serious give proper access for ventilation and inspection.

In addition to the solenoid brakes, hand brakes main operating motors when the operator is located house; otherwise an electric brake shall be employed. shall be of the band type, and shall be operated by the controllers. The brake shall have a braking normal starting torque of the motors. Hard maple steel bands shall bear on a cast-steel brake-wheel. friction between the blocks and the cast steel at twenty (20) per cent.

The brakes shall be of the type shown in Fig. 78a. support of the brake wheel; *B* and *E* are the supports

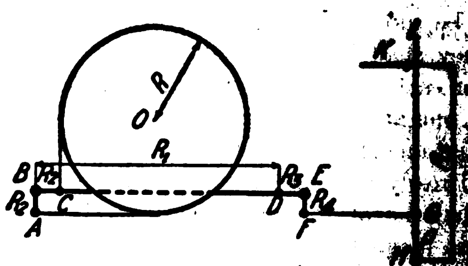

FIG. 78*a*. Hand Brake.

ABD and *DEF*, respectively; *A* and *C* are the the brake-band to the bell crank *ABD*; *H* is the *LH*, and *G* is the connection point for the link

Let K = Force applied on the brake-lever.

P = Force at the circumference of the brake-

R = Radius of the brake-wheel.

$T = PR$ = Torque to be overcome.

T_t = Pull in the brake-band on the taut side.

T_s = Pull in the brake-band on the slack side.

$$\lambda = \frac{T_t}{T_s}.$$

e = Base of the Naperian logarithms = 2.71828.

f = Coefficient of friction between the brake-wheel and the band-blocks.

θ = Angle of contact between the brake-band and the brake-wheel in radians.

Then $\lambda = e^{f\theta}$. (See Table 78*d*.)

$$P = T_t - T_s = (\lambda - 1)T_s.$$

$$T_s = \frac{P}{\lambda - 1}.$$

$$T_t = \frac{\lambda P}{\lambda - 1}.$$

$$T_s + T_t = \left(\frac{\lambda + 1}{\lambda - 1}\right)P.$$

$$K = \frac{(T_t + T_s) \times R_2 \times R_3 \times a}{R_1 \times R_4 \times R_5}.$$

TABLE 78*d*

VALUES OF λ FOR HAND BRAKES

Angle of Contact	Ratio T_t to $T_s = \lambda$	
	$f = 20\%$	$f = 30\%$
100°	1.418	1.688
120°	1.520	1.874
140°	1.630	2.081
160°	1.748	2.311
180°	1.874	2.566
200°	2.010	2.850
220°	2.155	3.164
240°	2.311	3.514
270°	2.566	4.111
300°	2.850	4.811

Where an electric brake is used, it shall be set by a spring and released by a solenoid. The brake will always be set except when the span is to be opened, when it will be released. If it is needed during the operation, it will again be set by cutting current off of motor. It shall be so designed that no injury will result if released indefinitely. There shall be a shunt circuit controlling the solenoid, and it shall be so arranged that the brake cannot operate while the motor is drawing current. A mechanical release

[illegible] on the controller within easy reach of
[illegible] operations performed by motive power
shall be used to cut off the current at each end of
[illegible] and gates, and at such a point near each
[illegible] that it will come to rest without jar. The limit
made that they will be capable of suitable adju
[illegible] spring switch normally open shall be
around the limit switches and allow the opera
to fully open or closed position, if necessary, after
has opened circuit.

The open and closed positions of the wedges,
shall be indicated to the operator by means of
to the switchboard. The lamps shall show
when the span is ready for traffic, and shall show red
Each signal must be sufficiently accurate to indicate
operation may be safely performed.

In addition to the previously mentioned
dicator shall be placed in the operator's house so as
of the span to the nearest foot at any time during
last two feet of the downward movement of the
the nearest inch. This indicator shall be placed
the operator can readily see it while operating the

All wiring shall be double-braided, rubber-covered
ample capacity to carry the currents required by the
mum loads without injurious heating and to provide
tion. No wires shall be less than No. 12 B. & S. gauge
be drawn without injuring them into loricated or
These conduits shall have as few bends as possible, and
connected to all apparatus so as to provide a weather
wires. In case alternating current be employed, all
(both feed and return) shall be placed in one
used, shall be so thoroughly made and arranged that
current to either the superstructure or the substructure

In draw-spans the supply cables may be brought
the river and up through the pier. In either case
be provided to conduct the current to the bridge
rings shall be protected from the weather. Ste
cables shall be used when the wires are placed
shall be separate cables for the supply and the
cable shall be composed of nineteen strands of
less than ninety-eight (98) per cent. conducti
shall be not less than five thirty-seconds ($\frac{5}{32}$)

contain not less than thirty (30) per cent of pure Para rubber. There shall be one winding of tape, and a lead sheath, three thirty-seconds ($\frac{3}{32}$) of an inch thick, the lead containing three (3) per cent of tin; also a substantial jute and asphalt covering and an armor of galvanized steel wire of suitable size for the diameter of the cable. The cables shall show at sixty degrees Fahrenheit an insulating resistance of five hundred megohms per mile after five minutes' electrification. All feed wires shall be protected by a pole-switch fuse and lightning arrester mounted on a non-combustible and non-absorbent insulating base.

In lift spans, vertical trolley conductors shall be placed on the front faces of the towers and shall extend for such a height that the collectors attached to the ends of the lift span can take current for any position of the span.

The contactors for making or breaking the electric circuits to operate the indicator lights or similar connections shall be of substantial design and of a type that has been operated successfully under similar conditions. They shall be protected from the weather and be easily accessible for inspection and renewal. All circuits shall be so arranged as not to interfere with the track signal circuit.

Switches of the quick-break type and of approved design shall be provided for each supply wire and for all circuits. They shall be mounted on the switchboard in the operator's house. The switches shall be designed to carry a current of not more than nine hundred (900) amperes per square inch of cross-section. Any knife-switch shall have a capacity of not less than one hundred (100) amperes. Emergency switches shall be used as noted on page 1704. Automatic circuit-breakers shall be placed on the switchboard to protect each motor circuit from excessive currents. All other circuits shall be protected by enclosed fuses. A voltmeter and an ammeter of ample capacity and standard make shall be placed on the switchboard.

A switchboard of first-quality slate and proper design shall be placed in the operator's house. It shall be of ample size to carry without crowding all meters, switches, fuses, circuit-breakers, indicator-lights, etc., and shall be attached well above the floor to a substantial frame. All apparatus on the board shall be properly labelled as to its use.

Electric lights of sixteen (16) candle-power shall be placed in the house so as to provide ample light for the house and for the inspection of the machinery. Lights with weatherproof sockets shall be used on the outside, on the stairs and walks, and at other points where needed. All lights shall be controlled by suitable switches. A light shall be placed over each indicating instrument or so arranged as to illuminate its dial.

Channel and signal lights shall be provided for the guidance of boats, as required by the U. S. Government.

Track signals when required will be furnished and installed by the railroad company, which will also furnish and put in place all levers and

interlocking devices between the signal
equipment.
bell, or other suitable signal, controlled from the
shall be installed to warn traffic that the bridge is
In selecting the equipment it should always be
[illegible] any particular locality requires special signals
this is sometimes the case.

92. *Internal Combustion Motors*

If a gasoline engine or other internal combustion
shall be of the most substantial construction, and
a torque, based on the rated horsepower of the motor,
per cent in excess of the maximum torque required.
of performing the operation in the time specified, and
speed not to exceed six hundred (600) feet per minute.
bridges an engine shall be installed for operating the
for operating the locks, wedges, and gates, when these
operated. On bridges of less importance a single engine
for all operations, in which case proper provision must
ing from one set of machinery to the other. Friction
employed to apply the load gradually to the engine.
4-cycle type, which rotate in one direction only, two
arranged in duplex, must be used so as to make
of the machinery in both directions. For the 2-cycle
clutch will be sufficient. Engines of ten (10) horsepower
be started by compressed air. Engines shall be either
cooled, as best suits the case in hand, and all
their complete operation shall be provided. The
placed outside of the engine house. Indicators shall
the positions of the span, locks, and wedges. Brakes
shall be provided as for electric operation.

MACHINERY EQUIPMENT

93. *General*

The machinery equipment shall include all parts
moves, as well as all parts by which the motion is
trolled, together with all details necessary to
All machinery shall be of simple but substantial
be designed so as to be easily erected and adjusted
tain its alignment after it is finally placed and
part of the equipment must be easily accessible
oiling, tightening, etc.; and the whole of it shall
part can be readily removed for repairs or

94. *Materials*

For the various parts of the machinery equipment, the following materials shall be used; but when the material is not mentioned in the specifications or on the plans, its character shall be determined by the Engineer.

For all structural parts—medium steel.

For rivets and bolts—rivet steel.

For equalizer-bars—medium or forged steel.

For keys, cotters, pins, axles, shafts, trunnions, screws, worms, and piston rods—rolled or forged steel. Shafting pins and trunnions over four (4) inches in diameter shall be of forged steel. Shafting under four (4) inches in diameter may be of cold-rolled steel.

[illegible] levers, cranks, connecting-rods, and rope-sockets—forged or cast steel. Rope sockets shall be drop-forged unless too large for the manufacturer's dies. In such a case either special dies shall be made or cast-steel sockets employed.

[illegible] the top, boxing, and base of pivot-stands, and for rollers, track, [illegible] and centre shoes, latch-castings, sheaves under thirteen and a [illegible] feet diameter, rims and hubs for sheaves over thirteen and a [illegible] feet diameter, guide and centring castings, toothed wheels, [illegible] couplings, and brake-lever stands—cast steel. Pinions shall be [illegible] forged steel unless they are too large for forgings, in which case [illegible] made of cast steel.

[illegible] discs, friction rollers, ball-bearings, footsteps of vertical [illegible] wherever desirable to reduce the bearing area, abrasion, or [illegible] hardened steel.

[illegible] castings—manganese steel.

[illegible] centre discs of pivots and the linings of journal bearings of [illegible] phosphor bronze for heavy loads and slow speeds.

[illegible] of shaft and footstep bearings and other rotating or sliding [illegible] to prevent seizing—phosphor bronze for light loads and high [illegible]

[illegible] metal may be used for light loads and low speeds.

[illegible] weight cables and operating cables—plow steel.

[illegible] may be used for unimportant parts, such as small shaft [illegible], etc.

95. *Loads*

[illegible] both the supporting and the operating machinery, the [illegible] be taken the same as those for which the power equip- [illegible]

96. *Unit Stresses*

[illegible] for the operating machinery, under normal condi- [illegible] in Table 78*e*; and those for the supporting ma-

[illegible]

[illegible] unit stresses may be increased [illegible] when operating by hand power with as many [illegible] each exerting a horizontal force on the [illegible] twenty-five (125) pounds.

TABLE 76

NORMAL UNIT STRESSES FOR OPERATING [illegible]

Material	Tension	Compression	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
Structural Steel	10,000	$10,000 - 40\frac{l}{r}$	[illegible]
Forged Steel Machinery Steel	12,000	$12,000 - 45\frac{l}{r}$	[illegible]
Cast Steel	8,000	$10,000 - 40\frac{l}{r}$	[illegible]

In equalizer bars the metal back of the pin shall [illegible] pounds per square inch, and the metal through the [illegible] pounds per square inch.

For parts such as shafting, in which the stresses [illegible] unit stresses shall be taken as one-half (½) of the [illegible] and for parts such as trunnions, in which the reversal [illegible] slowly, the unit stresses shall be taken at two-thirds [illegible] values for supporting machinery.

The strength of cut gear teeth shall conform to the [illegible] one tooth only being assumed to take the entire pressure.

$$W = spfy;$$

in which W = tooth pressure in pounds,

s = allowable intensity of working stress,

= 15,000 pounds for velocities under 120 [illegible]

$= 18,000 \left(\frac{600}{600 + v}\right)$ for velocities over 120 [illegible]

v = velocity in feet per minute,

p = circular pitch in inches,

f = face of tooth in inches,

and y = factor depending on number of teeth.

---

* With $\frac{l}{r} = 25$ and less, use 9,000 lbs. for structural and [illegible] for forged and machinery steel.

TABLE [illegible]

[illegible] y FOR GEARS WITH 20° INVOLUTE TEETH

No. of Teeth	y	No. of Teeth	y	No. of Teeth	y	No. of Teeth	y	No. of Teeth	y
[illegible]	[illegible]	22	.105	32	.116	43	.126	85	[illegible]
[illegible]	[illegible]	23	.106	33	.117	45	.127	[illegible]	[illegible]
14	[illegible]	24	.107	34	.118	47	.128	[illegible]	[illegible]
15	[illegible]	25	.108	35	.119	48	.129	100	[illegible]
[illegible]	[illegible]	26	.109	36	.120	50	.130	110	[illegible]
[illegible]	[illegible]	27	.111	37	.121	55	.132	[illegible]	[illegible]
18	[illegible]	28	.112	38	.122	60	.134	140	[illegible]
19	[illegible]	29	.113	40	.123	65	.135	150	[illegible]
20	[illegible]	30	.114	41	.124	70	.137	200	[illegible]
21	.104	31	.115	42	.125	80	.138	Rack	[illegible]

[illegible] allowable stresses per square inch for bearing on rotating and sliding surfaces shall be as follows:

For Slow and Intermittent Speeds:

Pivots for swing bridges, hardened steel on phosphor bronze . . . . 3,000 lbs.

Journal bearings for trunnions of lift and bascule bridges, steel on phosphor bronze . . . . 1,500 lbs.

Rollers, cast steel on cast steel, cast iron, structural steel, or bronze . . . . 500 lbs.

Pressure transmitting motion, on projected area of screw thread . . . . 200 lbs.

For Ordinary Cases, Moderate Speeds:

Hardened steel on hardened steel . . . . 2,000 lbs.

Hardened steel on phosphor bronze . . . . 1,500 lbs.

Tool steel (not hardened) on phosphor bronze . . . . 900 lbs.

Machinery steel on bronze . . . . 600 lbs.

Machinery steel on Babbitt metal . . . . 400 lbs.

Structural steel on cast iron . . . . 400 lbs.

In order to prevent heating and seizing at high speeds, the pressure on pivots or footstep bearings for vertical shafts and journals shall not exceed the following:

For pivots . . . . $p = \dfrac{80,000}{nd}$,

For journals . . . . $p = \dfrac{300,000}{nd}$;

where n = number of revolutions per minute,

d = diameter of journal or pivot in inches,

p = pressure in pounds per square inch.

For wrist pins and similar joints with alternating motion the above values may be doubled.

The allowable pressure in pounds per lineal inch of roller in motion

For cast iron.............................

For cast steel...........................

For machinery steel......................

For untreated tool steel.................

For hardened tool steel..................

where p = pressure in pounds per lineal inch of
and d = diameter of roller in inches.

The preceding values are for rollers and bearing
material; for different materials the smaller value

The allowable pressure on balls of hardened
surfaces of the same material shall be as follows:

For balls running on flat surfaces..........

For balls running in grooves of radius $\frac{2d}{3}$..........

where p = permissible load in pounds per ball,
and d = diameter of ball in inches.

The preceding values for rollers and balls in motion
for rollers and balls at rest.

The total stress in the operating ropes and the
shall consist of the direct and bending stresses.
equal the direct load on the rope. The bending
mined from the following formula,

$$K = \frac{Ea}{2.06\frac{R}{d} + c}$$

where K = bending stress in rope,
E = modulus of elasticity = 28,500,000,
a = metallic area of rope in sq. in.,
R = radius of sheave in inches measured to
d = diameter of wire in inches,
and c = constant = 15.45 for 6 × 19 rope.

For the counterweight ropes, the ratio of the
stress (including bending) shall not be less than two
the ultimate to the direct not less than six (6).

For the operating ropes the direct load shall be
pull required to start the span. The ratio of the
total stress shall not be less than one and one-half
of the ultimate to the direct not less than five (5).

Tables 16a and 16b give the weight, areas,
limits, and bending stresses of 6 × 19 wire ropes

Rope sockets shall have an intensity of
65,000 pounds when the attached ropes are

[illegible] 16c and 16d give the dimensions for span and closed sockets, respectively, for different sized ropes.

DESIGNING AND DETAILING FOR MACHINERY OF MOVABLE SPANS

97. *Track, Rack, Rollers, and Centre Casting for Rim-Bearing Draw-spans*

The tracks and rollers for rim-bearing swing spans shall be so designed as to provide a support for the swing span that will maintain exact alignment and will distribute the loads properly to the masonry. The entire dead load shall be carried by the rollers while the span is swinging, and the entire dead and live loads on the pivot pier shall be carried thereby when the span is closed.

The upper track shall be made of segments of sufficient thickness to distribute the load properly between the rollers and the drum. The top face of this track shall be planed smooth so as to form close contact with the bottom flange of the drum, and the lower face shall be planed conical so as to fit closely to the conical rollers. All joints between segments are to be planed smooth and to such bevel as to ensure perfect contact with each other. These track segments are to be riveted or bolted to the bottom flanges of the drum with fifteen-sixteenths ($^{15}/_{16}$) inch rivets or bolts, placed opposite, and spaced not to exceed fifteen (15) inches between centres. The heads of these bolts or rivets are to be countersunk in the track on the side next to the rollers. No rust cement or any other composition is to be used between the track and the drum.

The lower track is to be made strong enough to distribute the load from the rollers uniformly over the masonry. Its top is to be planed to a true conical surface to fit closely to the conical rollers. The bending moment on the lower track is to be found by the formula,

$$M = \frac{1}{12} Wl,$$

where M = greatest bending moment on lower track, W = total load on [illegible] and l = distance from centre to centre of adjacent rollers, [illegible] the centre line of the track. The lower track shall be made [illegible] from six (6) to eight (8) feet in length. All abutting ends of [illegible] segments are to be planed smooth, are to have close contact [illegible] and are to be bolted together at each joint by not less than [illegible] through holes in lugs cast thereon. These bolts are to [illegible] fifteen-sixteenths ($^{15}/_{16}$) of an inch in diameter. In no case [illegible] track be less than two and one-quarter (2¼) inches thick [illegible] or one and three-quarters (1¾) inches for highway spans, [illegible] less than two and one-half (2½) inches thick for rail- [illegible] (2) inches for highway spans, measuring on the central [illegible] of the drum.

[illegible] shall be anchored to the top of the pivot-pier with [illegible] one (1) inch in diameter, nor less than fifteen (15)

[illegible] They [illegible] the chords of the drum [illegible] (?) inches between centres. [illegible] The rollers shall be of cast steel, and [illegible] the centre hole and four or more [illegible] for the double purpose of [illegible] and uniform cooling the [illegible] the diameter of the roller. In no case shall [illegible] twelve (12) inches in diameter and seven (7) [illegible] nor less than ten (10) inches in diameter [illegible] for highway spans. All rollers, and the faces of [illegible] tracks which are in contact with the rollers, are [illegible] the forms of right frustums of cones the vertices [illegible] the centre of the drum, so that the rollers will have [illegible] the tracks throughout their travel around the [illegible] bearing is to be turned in the centre of each roller [illegible] oil-holes are to be provided on both the interior and [illegible] the rollers, so that these bearings can be kept [illegible] bosses must be provided on both the inner and [illegible] roller, to bear against the collars and the friction [illegible] ends of the radial rods are to pass through the rollers [illegible] are to attach to a circular plate fitting closely around [illegible] These radial rods are to be provided with nuts for [illegible] of the rollers. Only square sections are to be used [illegible] must contain at least one square inch of section. [illegible] passing through the roller must be upset so as to [illegible] for the latter at least one and one-half (1½) inches [illegible] outer ends of these rods are to pass through a stiff [illegible] built channel section, which is to serve as a spacer [illegible] channels must be made wide, but not deep, and [illegible] commensurate with the size of the turntable. They [illegible] from the rollers by friction-washers on the rods. [illegible] rollers collars are to be forged and turned on the [illegible] said rollers in exact position on same. An inner [illegible] commensurate with the magnitude of the drum, is [illegible] radial rods. For small bridges this ring may [illegible] with a pair of small lug angles riveted thereto for [illegible] as near the inner ends of the rollers as practicable. [illegible] arrangement should be somewhat modified by [illegible] the form of a small curved plate-girder lying in [illegible] rigidly braced to the centre casting by radial [illegible] the outer ends to the curved girder and at the inner [illegible] lar plate which fits snugly around a turned bearing [illegible]

[illegible] to be shortened [illegible] to the circular girder instead of to a plate at the [illegible] should be not less than two and a half [illegible] should not be less than three (3) inches in diameter [illegible] at both ends of the bars so as to move the [illegible] drum; and the inner ends of the bars are to be so [illegible] plate as to permit of the correction of any slight [illegible] a truly radial direction.

[illegible] casting must be made strong and heavy, and must be [illegible] anchored to the top of pier by eight (8) or more anchor-bolts [illegible] one and one-fourth (1¼) inches in diameter and not less [illegible] (3) feet long for railway structures nor less than one and [illegible] (1⅛) inches in diameter and two and one-half (2½) feet long for [illegible] structures. These bolts are to be made of soft steel, with [illegible] at top, and with split ends and wedges at bottom. The least [illegible] thickness of metal for this casting shall be one and one-half [illegible] for railway spans and one (1) inch for highway spans. The [illegible] be true and level; and an even bearing shall be secured by [illegible] in neat Portland-cement mortar. For heavy draws this casting [illegible] to be set well into the masonry, then grouted in place. All [illegible] plates which rotate on this casting are to be turned smooth [illegible] with suitable oil-grooves, so they may be easily oiled. A [illegible] holding down the top connection-plate for the radial struts [illegible] to the top of the centre casting.

[illegible] for turning the span is to be made in short sections, not over [illegible] so that in case of breakage only a small portion need be [illegible] These rack segments are to be bolted to the lower track with [illegible] less than fifteen-sixteenths (15/16) of an inch in diameter, [illegible] to exceed fifteen (15) inches between centres. In any [illegible] be enough of them in any one segment of the track to [illegible] proper margin for contingencies, the entire shear, and also the [illegible] to the rotating moment caused by the tooth pressure of the [illegible] that engage with the said segment. The least allowable [illegible] metal in the rack shall be one and one-eighth (1⅛) inches. [illegible] rack segments are to be planed so as to secure close con- [illegible] abutting ends are to be bolted together with turned bolts [illegible] eighths (⅞) of an inch in diameter. The bottom of the [illegible] portion of the lower track upon which the rack bears are [illegible] smooth. The width of the base of the rack shall be at least [illegible] of its height; and ribs bracing the vertical portion to the [illegible] provided at distances not exceeding eighteen (18) inches. [illegible] about one inch in diameter, spaced not more than two [illegible] centres, shall be bored in the lower-track segments, [illegible] of the rack and leading to the outside of the

[illegible] *Pivot, Wheels, Rack, and Gallery for* [illegible]

[illegible] bearing swings, the centre pivot
load of the span both when swinging and
be composed of a cast steel base supporting a
or ball-bearing that carries the top casting on
is directly supported. The disc-bearing has
shall generally be used. The phosphor-bronze
vex on both faces and shall lie between two
have curved surfaces bearing on the centre
radius. The other surfaces of these discs shall
on the upper and the lower castings and be
sure that the sliding shall take place on the
cast-steel box shall be placed around these
base casting. This box shall be of substantial
clearance of one-thirty-second ($\frac{1}{32}$) of an inch
the box. It shall be made in sections and bolted
removal for the inspection and the renewal of the
necessary. Semi-circular vertical oil grooves of
placed around the inside of the boxing and
around the top. Oil holes feeding into this oil
in the top casting. The latter shall completely
from dust, etc. Oil grooves of three-eighths ($\frac{3}{8}$)
in diametral lines across both faces of the
inch in diameter shall be drilled in all three
hole shall feed into oil grooves cut on diametral
of the base casting. Holes shall be drilled into
of these grooves and tapped for drain pipes.
at the discs shall be polished, whereas all other
finished. The base casting shall be well anchored
than eight bolts, each one and one-half ($1\frac{1}{2}$) inches
(3) feet long.

The circular track for steadying the span
operating rack are to be cast separately in
effectively so that broken rack segments may be
previous specifications are to govern the design of
excepting that the track may be as narrow as
ally there are to be six (6) or eight (8) trailing
teen (18) inches in diameter and six (6) inches
less than three (3) inches in diameter. The
dial position so as to run truly on the track;
fastened in correct position. Provision shall be
rollers so that they will just clear the track
The rollers and support shall be designed to
teen (15) pound wind tending to overturn the

Centre Wedges for Centre-Bearing Swing Spans

When the span is closed, the live load shall be carried on the centre wedges. They shall not be designed to lift the trusses but merely to provide a good, firm bearing. For this reason a flat bevel of about one (1) to ten (10) is desirable. Two wedges, one at each side of the pivot near the trusses, will generally suffice. Proper provision shall be made for adjustment. The wedge shall bear on an upper casting provided with guides engaging lips on the wedge. These guides and lips shall be so arranged that the wedge will be supported by the upper casting during the swinging of the span. The wedge shall bear on a base casting substantially bolted to the pier.

100. *End Lifts for Swing Spans*

All swing spans shall have an arrangement to lift the ends thereof so as to make the span continuous over the centre supports for all conditions of loading. Wedges, toggle-joints, eccentrics, and rollers with links may be used for this arrangement. Whatever detail is employed, it shall be [illegible] lift the ends to the desired elevation and form a solid, substantial [illegible] as for fixed spans. In figuring the amount of movement to be [illegible], the possibility of the top chord's having a temperature 20 [illegible] greater than that of the bottom chord must be duly considered. [illegible] give very satisfactory supports. When used they shall move [illegible] line of the trusses and bear directly under the same in the line of [illegible] floor-beams. The upper surface of the wedge shall be beveled [illegible] one (1) to five (5), and shall engage guides in the upper bearing [illegible] which is directly attached to the truss so that the wedge will [illegible] by the span when swinging. The lower surface of the wedge [illegible] horizontal, and shall bear on the base casting that is bolted di[illegible] the pier. The base casting shall have guides to engage the [illegible] these guides must not interfere with the span while swinging. [illegible] in contact are to be finished and polished.

[illegible] roller bearings are employed, rollers are to be provided be[illegible] end-pins of the trusses and attached to the span by means of [illegible] operated by struts attached to the pins passing through [illegible]. The axes of the rollers shall be parallel to the trusses and [illegible] during operation in a transverse direction. The rollers [illegible] so as to provide a fairly close fit over the pins at the bot[illegible]. Both the pins and the insides of the rollers must be [illegible] smooth, and provision must be made for oiling the bearings [illegible]. No roller shall be less than six (6) inches in diameter, and [illegible] them shall not be less than three and one-half (3½) [illegible] bridges where, on account of infrequent operation [illegible] changes of temperature, there is a tendency to drag

[illegible]

[illegible] shoulder must be [illegible] in its final position with the [illegible] of these shoulders shall be about [illegible] the roller, but never enough to interfere [illegible] shoes at each end of the span shall be [illegible] not less than one and one-half (1½) inches [illegible] enough to take up the entire thrust from the

A toggle arrangement may be used, the upper [illegible] to the truss by a pin, and the lower end [illegible] moving in vertical guides. The [illegible] through the toggle links to the upper pin [illegible] arm is to be attached at the centre [illegible] the plane of the truss. In connection with [illegible] rollers with transverse axes may be [illegible] which the spans open very infrequently and [illegible] are great, so as to minimise the effect of the [illegible] of the steelwork. These rollers shall be provided [illegible] ing them into correct vertical positions when the [illegible] provision shall be made for adjusting the bases.

For bob-tailed draw spans it is usually best to [illegible] the end of the long arm only.

Proper provision for adjustment must be made

101. *Latch for Swing Spans*

To bring the draw span to rest and proper position automatic latch of the Pencoyd type shall be used. at the centre of each end floor-beam.

102. *Suspending Cables for Vertical Lift*

In vertical lift bridges the movable span shall be terweight at each end, connected to the span by sheaves at the tops of the towers.

These counterweight ropes shall be of plow steel six (6) strands of nineteen (19) wires each, laid They shall be of approved make and shall conform Table 16*a* as to their elastic limits and ultimate shall be designed as noted under "Unit Stresses" small side leads as possible, in no case exceeding

[illegible]

$$S = \frac{LP}{Ea}$$

[illegible] in inches,
[illegible] = calculated length of rope in inches,
[illegible] stress in pounds,
[illegible] = modulus of elasticity for stretch,
= [illegible],000,000,
and [illegible] = metallic area of rope in inches.

[illegible] manufactured length shall be the calculated length [illegible] stretch in the ropes. The manufactured lengths of the ropes [illegible] vary from the dimensions indicated on the drawings by greater amounts than those given in Table 78g.

TABLE 78g

ALLOWABLE VARIATIONS IN FABRICATED LENGTHS OF WIRE ROPES

Manufactured Length	Variations (+ or −)
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

103. *Rope Sockets*

[illegible] shall be either open or closed as required. They shall [illegible] standard dimensions shown in Tables 16c and 16d.

104. *Equalizers*

[illegible]weight ropes shall, as a rule, be connected directly to [illegible] the lift-span side, but on the counterweight side they [illegible] to equalizers, which, in turn, are attached to the coun-[illegible] equalizer bar shall be made with the centre pin below [illegible] distance will depend on the layout and design of [illegible] no vertical links shall be used between the bars [illegible] the direction, as noted below. The layout of the equal-[illegible] on the type of counterweight used, whether sectional or [illegible]tional type four ropes shall generally be attached to each [illegible] equalizer bars shall be placed parallel to the axis of the [illegible] counterweight, the upper equalizer bars, to each of [illegible] attached, shall, as a rule, be placed transversely to [illegible] They shall be attached to the lower equalizer bars;

which run parallel to the axis of the
upper side, open sockets shall generally be
side, closed sockets. All pins connecting the
have a head one-quarter (¼) inch thick on
the other. The pin connecting the bottom
hanger shall have the ends threaded for
made for removing any pin connecting the
in case it becomes necessary to replace a rope,
so designed that a rope can be replaced without
weight. All pins in the upper equaliser bars
viz., that used for the sockets. The clearance
shall be greater than one-half (½) inch, which
no clearance.

105. *Tower Sheaves*

Tower sheaves having a pitch diameter of
feet and under shall be made of cast steel, and
shall be built up of structural steel with a cast-steel
pitch diameter of the sheave shall not be less than
diameter of the rope. The ropes shall be spaced
apart equal to the diameter of the rope plus
The grooves in the sheaves shall be made to fit
between the grooves shall be rounded off with the
one-eighth (⅛) to one-quarter (¼) inch below
tance from out to out of rim shall be equal to the
centres of the end ropes plus two (2) diameters of
of the rim shall project one-half (½) the
the pitch line. The inner face of this lip shall
(15) degrees with the vertical.

Tower sheaves shall have not less than eight (8)
tee, cross, elliptical, or H in section. Each rib shall
to carry the load on the sheave, distributed over
distance from centre to centre of spokes, and to
to the friction on the journals. In all cases where
two ribs, one at each side of the sheave, the rim
ported between these sections for its full width.
supported longitudinally between the spokes.
diameter shall be one and eight-tenths (1.8) times
shaft, but shall not exceed the said diameter by
The hub shall have a greater length than the
of rim. It shall be made to bear on the shaft
side under the spokes.

Structural sheaves shall be built up of plates
line of the said sheaves, one or more being used
a segmental cast-steel rim and connected by

plates should have openings in them between these diaphragms. These plates shall bear on the shaft and shall be reinforced for bearing by additional plates and the hub castings. The latter shall consist of circular discs on the outside and a spool between the webs. The inside casting shall extend across the journal for the full width between plates, but shall bear on the journal only the required amount at each side. The webs, reinforcing plates, and castings shall all be riveted up and then bored for the shaft.

The rim sections shall have side flanges for connection to the side plates of the sheave and cross ribs at each diaphragm. These cross ribs shall be riveted or bolted to the diaphragms. The entire load from the ropes shall be delivered from the rim to the structural part of the sheave by rivets or turned bolts, no reliance being placed on any bearing that may exist. All abutting surfaces shall be finished for perfect contact. The grooves in the rim shall not be turned until the segments have been assembled and riveted or bolted to the structural work. Drain holes shall be provided in all sheaves where water is likely to collect.

106. *Tower-Sheave Shaft*

The shaft for the sheave shall be designed for the greatest bending and shearing stresses that may come on it. The diameters of the portions in contact with the sheave shall be greater than that of any other part of the shaft, the diameter at one bearing point, and the corresponding bore in hub metal, being not less than one-sixteenth ($^1/_{16}$) of an inch larger than that at the other. The sheave shall be pressed on the shaft, and not less than three keys shall be used between the sheave and shaft. They shall be designed for a shearing force equal to twenty (20) per cent of the total load on the sheave. The bearing surface of each journal shall be of a length not less than the diameter thereof plus two inches. It shall be highly polished. Where the cross-section of the shaft changes, fillets shall be used.

Beyond the bearings the ends of the shaft shall be shouldered and likewise filleted. When the journal diameter exceeds eight (8) inches, a hole, having a diameter equal to one-fourth ($\frac{1}{4}$) that of the journals, shall be bored through the shaft for its entire length. Oil grooves one-quarter ($\frac{1}{4}$) inch wide and one-half ($\frac{1}{2}$) inch deep shall be cut in the journals parallel to the axis of the shaft. They shall be machine-cut with the upper edges rounded off. Provision must be made for cleaning the grooves. A large well shall be bored in each end of the shaft and connected with the oil grooves. In case the centre of the shaft is bored out, the inner ends of the wells shall be screw plugged. The outer ends shall also be screw plugged and tapped for marine-type, screw-feed grease-cups of not less than one pint capacity.

[illegible] in the casting. The [illegible]
[illegible] bosses shall be provided
heads of the bolts. The joints between the
[illegible] and shims shall be furnished
shall be provided with a bushing.
for high bearing pressure and low speed.
than one-twelfth ($^1/_{12}$) of the diameter of the
five-sixteenths ($^5/_{16}$) inches. All bushings shall
bases. They shall be scraped to fit their
for field erection. When considered advisable
designed so that they may be removed and
caps shall be provided with eye-bolts for handling.

108. *Sheave Hoods*

The sheaves shall be protected by hoods
attached to the towers. These hoods shall
plates of number sixteen (16) gauge, the former
than the extreme radius of the sheave and
angles. The side plates shall be six (6) inches
the ropes from the weather.

109. *Guides for Vertical Lift*

The lift span shall be held in alignment by
the four corners at the top and the four at the
gaging tracks riveted to the front tower columns.
of either the roller or the sliding type. They shall
to the span so as adequately to provide for all
on them. They shall be designed for a fifteen
except as hereinafter provided. All guides shall
of movement longitudinally, excepting the bottom
end of the span, which shall be arranged so as to
be ample clearances between the guides and the
be made for the field adjustment of the relative
tracks. Where the guide castings also adjust the
either longitudinally or both longitudinally and
place of centring castings, they shall be designed
wind pressure, also for the thrust from braked
road bridges.

110. *Centring Castings*

The lift span shall, as a rule, be brought to exact position when closed by means of centring castings, generally attached to the four lower corners of the span, which engage castings attached to the towers. The castings shall be arranged so as to hold one end of the span fixed and allow longitudinal movement of the other end. The castings shall be designed for a [illegible] assumed wind load on the span, and in addition those at the fixed end [illegible] the traction load in case of railroad bridges. Where [illegible] railroads pass over the structure, the span shall be centred [illegible] of the rail plus one (1) inch above its lowest position. The [illegible] faces of the engaging and engaged castings shall have bevels not to exceed one (1) in twelve (12). Proper provision shall be made for adjusting the centring castings in the field.

In highway bridges the centring may be taken care of by means of guide castings by flaring the track at the lower end. In low lifts the clearance in the guides may be made so small that further provision will be unnecessary for centring the span. But where the lift is great and [illegible] a large transverse clearance has to be provided in the guides on [illegible] possible irregularities in the guide tracks or because of the [illegible] of trusses, causing excessive changes in length of lift-span [illegible], the final transverse centring shall be done by special con[illegible]. These shall be attached to the end floor-beams at the centre, [illegible] be designed for the transverse wind only. Especially is this [illegible] where a street railway passes over the bridge. Where a wide [illegible] is used in railroad bridges, the same arrangement must [illegible]. The traction load in such a case will have to be taken [illegible] centring casting or by the guide castings.

[illegible] in the centring castings shall be such that the guide [illegible] will not tend to centre the span. One-eighth (⅛) inch [illegible] each way will suffice.

[illegible] castings shall also be provided on bascule spans at the

111. *Rail Locks*

[illegible] of all movable spans provision shall be made for making [illegible] continuous. Loose rails shall not be used. In lift bridges man[illegible] castings may be bolted to the rails on the lift span and [illegible] openings on to bearings, engaging the rails and the sup[illegible] the fixed spans. A portion of the head and base of the [illegible] off on the outside so that the casting can be fitted to [illegible] at its outer edge shall be one-eighth (⅛) of an inch [illegible] over the opening, the top surface having a bevel [illegible] (20) toward the inside. The ends of the [illegible]

shall be depressed below the top of
casting shall have a gradual rise
same arrangement may be used on the
of the fixed span at the opposite end.
be used on swing spans, but the
back from the opening so that it can be
spans and thus prevent interference in
expansion plates shall be lifted by the
In railway spans the openings between
spans shall, preferably, be bridged by
movable span. These shall engage the rails
fixed spans.

112. *Span Locks and*

An arrangement for locking the span in
used for all movable spans. It shall be of
design.

Hydraulic or other buffers of approved type
for bringing both lift and bascule spans to rest
as some engineers consider it legitimate to rely
accomplish this result, it may not be
buffers.

113. *Rack Pinions for Swing*

Swing spans shall be turned by pinions
essary gearing being introduced between the
to open and close the span in the required time.
employed, they shall be placed diametrically
sures shall be equalized by differential gearing in the
Where four pinions are used, they shall be placed
in pairs, and the two pinions of each pair shall be
as practicable and equalized by gearing. Each
operated by a separate motor. The two motors
the same controller, thus equalizing the action of

114. *End Lift Machinery for Swing*

The end lifting and locking machinery shall
duction at the ends of the span so that the line
high speed and light torque. The centre wedges
shall be operated at the same time the end lifts are
mechanism shall be so adjusted that the centre
firm bearing at the same time that the ends of
the required amount.

115. *Operating Ropes for Lift Span*

The lift span shall be raised and lowered by means of operating ropes at each side of the span attached to drums at the centre and passing over deflecting sheaves at each end of the span to the top and bottom of the towers. Either one or two ropes for raising and the same for lowering shall be used at each corner, the number depending on the force required to move the span. These ropes shall be fastened to the drums with forged-steel clips. A take-up device attached to the towers shall be provided at the ends of the operating ropes to take up any slack therein. This mechanism shall consist of a turnbuckle, bolt and nut, or drum. If a drum is used, it shall be operated by a worm gear with the worm fitted for a hand-turning lever. The operating ropes shall never be less than three-quarters (¾) of an inch in diameter. They shall be of six (6) strands of nineteen (19) wires each, and shall conform in general to the requirements given for counterweight ropes.

116. *Operating Drums for Lift Spans*

There shall be either two or four operating drums located at the sides of the span at the centre thereof. For small spans two drums shall be used, one at each side; and they shall be grooved so as to take the ropes from both ends of the span. For larger spans four drums shall be employed, two at each side. In girder spans where four drums are used, one drum shall be placed at each corner of the span. Each drum shall be grooved to take the ropes from the corresponding end. The diameter of the drum from centre to centre of ropes shall be not less than forty (40) times the diameter of the operating rope, except where a rope less than three-quarters (¾) of an inch in diameter will figure for direct load and bending or where the ratio of the ultimate strength to direct bending is greater than six (6), in which case the drum diameter may be thirty (30) times the diameter of the rope. The distance from centre to centre of ropes shall equal the diameter of the rope plus one-sixteenth ($^1/_{16}$) inch. Care shall be taken to see that the holes in the drums through which the ropes pass are large enough to pass both the rope and the mousing. The grooves in the drum shall be finished to fit the ropes, and the metal between the ropes shall be rounded off as in the tower sheaves. The number of grooves shall be such that when either the up-haul or down-haul ropes are payed off to the extent of the travel of the lift span, these ropes will still have one and one-half (1½) turns wrapped on the drum. All parts of the drum shall be of ample strength to withstand the pull in the operating ropes. The hub shall extend about one-half (½) inch beyond the outside of the drum at each end.

[illegible]

[illegible] deflecting sheave at the ends [illegible] at the operating drums [illegible] which shall be spaced [illegible] the diameter of one rope plus [illegible]. The outside flanges of the [illegible] one-half diameter of the rope above its [illegible] flanges shall make an angle of fifteen (15) [illegible] the distance from out to out of rim shall be [illegible] of metal at the edges. The rims and

The deflecting sheave shall have not fewer than be tee, cross, or elliptical in section. The shaft supported by the structural work. The and tapped for marine-type, screw-feed screwed into the bushing. Proper provision for lubrication. A small idler sheave shall be ing sheave and toward the centre of the span rope and prevent it from leaving the deflecting

118. *Supports for Operating*

Where necessary to support the operating drum and the deflecting sheave, or to keep the gum-wood rollers shall be used. They shall be less than six (6) inches—that the rollers will from dragging on and cutting grooves in at as many points as necessary to support the curved top chords they shall be located at each mediate points, if needed.

119. *Operating Machinery in*

The machinery between the motors and the pinion shall be as compact as possible, and shall as good designing will permit. The layout shall good, economical design with as few parts as

120. *Operating Machinery for*

In a swing span the main machinery shall the span, either below the floor, in case there an arrangement, or up between the trusses, or if the headway be restricted.

121. *Operating Machinery for Lift Spans*

In a lift span the machinery shall likewise be placed at the centre of the span either on top of the trusses or between them. Where four drums are used, one reduction shall be installed at the drums. A single shaft shall extend out from the main machinery in the house with a pinion at the end engaging duplicate gears fastened to the drums.

122. *Gears*

All gears shall have twenty (20) degrees, involute, machine-cut teeth. They shall be designed by the rules given under "Unit Stresses," page 1710. The sides shall be faced and the pitch lines scribed on both sides. The face width of a gear shall be from two (2) to three (3) times the circular pitch. The thickness of the rim shall not be less than four-tenths ($^4/_{10}$) of the circular pitch plus one-quarter ($\frac{1}{4}$) inch. All gears employed between the motive power and the operating drums or rack shall have at least six (6) spokes or else solid webs; those employed to drive limit switches, mechanical indicators, etc., may have four (4) spokes. The spokes may be elliptical, tee, or cross in section. They shall be figured as cantilever beams free at the pitch line and fixed at the hubs, each spoke taking its direct proportion of the load on the tooth. The hub diameter shall be one and eight-tenths (1.8) times the diameter of the shaft, but not to exceed the said diameter plus ten (10) inches. The hubs shall be faced and shall have a length greater than the face of the gear.

Bevel gears shall be avoided as far as possible.

123. *Worm Gears*

Worm gears may be used for minor operations. The worm shall be below the gear and shall run in oil. It shall be made of forged or rolled steel, and the gear shall be of bronze. The end of the worm shall bear on a bronze collar, and the shaft of the gear shall rotate in bronze bushings. The gear shall have not less than twenty-eight (28) teeth. The threads on worms shall be cut, and the gear teeth must fit the worm accurately. A standard worm set shall preferably be used.

124. *Pinions*

Pinions, as a rule, shall have not less than seventeen (17) teeth. Under certain conditions, as in the pinion engaging the rack in draw spans, the use of fifteen (15) teeth may be allowed, in which case stub teeth will probably have to be adopted to give swinging clearance. The face width of pinion shall be from two and one-half ($2\frac{1}{2}$) to four (4) times the circular pitch and always greater than that of the gear it engages. The

hubs shall be as specified for gears.

the gear to the pinion shall not exceed

125.

All shafting shall be designed for an equi

$$M = \tfrac{1}{2}M_1 + \tfrac{1}{2}$$

Where M_1 = Bending moment on the shaft,
and M_2 = Twisting moment on the same.

A proper reduction shall be made for the

diameter of the shaft. The minimum diame

two and one-half (2½) inches. The unsupported

ing their own weight shall not exceed

$$l = 80\sqrt[3]{d^2};$$

and for shafts carrying gears, etc.

$$l = 50\sqrt[3]{d^2};$$

where l = length of shaft between bearings in

of shaft in inches. All shaft journals shall be po

126. *Keys*

Keys shall be designed so as to develop the

The width of the key shall generally be about

diameter of the shaft, and the depth shall be abo

or slightly less. In all cases, however, the keys

shearing and bearing within the unit stresses spe

the keys shall not be less than the length of the

not be used except in special cases; and all keys

keyways so as to have perfect bearing on all faces

used wherever there is a possibility of sliding on

be made safe by having the heads protected in co

hubs. Where it becomes necessary to remove

be extended so that it will be possible to drift

Where more than one key is employed they shall

and twenty (120) degrees apart. Keys shall be

spokes.

127. *Bearings*

Bearings shall be provided for the shafting

ing as possible. As far as it is practicable to

be arranged in a compact unit; and a single

for all the shafts in the unit. The bearings, however, shall be so laid out that any gear can be removed without disturbing the other gears. Where bevel gears are employed, the bearings for each set shall be in one piece. Single bearings shall be provided at all points where it is necessary to support the shaft in accordance with the rules given for unsupported length. All bearings shall be split bearings with finished joints; and shims shall be provided between the cap and the base for adjustment. The caps for large bearings shall be bolted to the bases with four turned bolts, and for small bearings with two such bolts. Finished bosses shall be provided for the bearing of all nuts and heads of bolts. The bolt holes shall be drilled. In large bearings the caps shall be provided with eyebolts for handling. Bearings shall be bolted to the steelwork with turned bolts having a driving fit. The bearings shall be assembled on the steelwork at the shop and the holes drilled while they are thus assembled, where it is possible to do so. When this cannot be done, they shall be drilled to an iron templet in both the casting and the steelwork.

128. *Bushings*

All bearings, unless specially noted otherwise, shall have bronze bushings, the thickness of which shall be one-twelfth ($^1/_{12}$) of the diameter of the journal. They shall be split at the juncture of the cap and the base castings, and shall be held against turning by the shims between [illegible]. The bushings shall be grooved for lubrication, and the grooves [illegible] be of such depth as to permit cleaning. If possible, all bushings [illegible] be so designed as to permit renewals. Bushings shall be scraped to the journals. Effective lubrication of journals shall be provided. [illegible]-feed grease-cups shall generally be used.

129. *Couplings*

[illegible] couplings shall be of the claw or flange type. In general claw [illegible] shall be used, especially where the shaft runs from the centre [illegible] to the ends, or where deflections of the structural work would [illegible] to bend and bind the shafting. The two claws forming [illegible] shall be finished for a close but not a tight fit. In flange [illegible] two parts shall be connected by turned bolts with a driving [illegible] shall be shrouded so that the projecting heads of bolts may [illegible] of danger. The hubs of couplings shall be one and eight- [illegible] the diameter of the shaft, but shall not exceed the said [illegible] (10) inches. The length of the hub shall be governed [illegible] the key, but must never be less than the diameter of the [illegible] shall be designed for the strength of the shafting [illegible] in general, they shall conform to the dimensions in [illegible] of the shaft, given in Figs. 78*b* and 78*c*.

[illegible] degrees apart shall be used in [illegible]

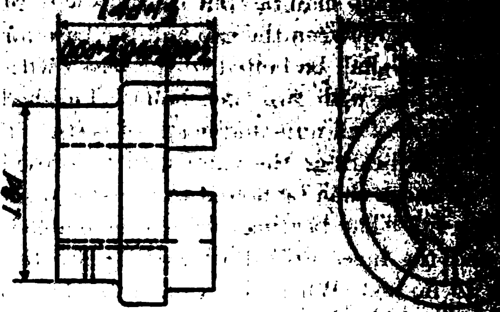

Fig. 78b. Jaw Coupling

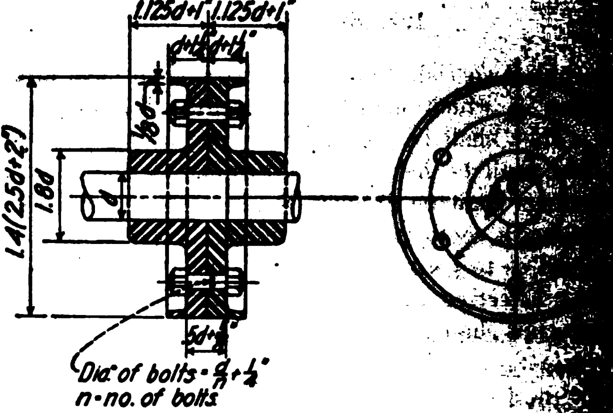

Fig. 78c. Flange Coupling.

131. *Friction Clutches*

Friction clutches of an approved standard
where internal combustion motors form the motive
be of substantial construction and shall be capable
maximum torque of the motor. (See also Paragraph

132. *Screws*

Screws which transmit motion shall have square

133. *Levers*

Levers used in performing the various operations
as to be convenient for the operator. They shall

[illegible] shall be used where it is necessary for [illegible] to be held in more than one set position.

134. *Turned Bolts*

Turned bolts shall be employed where a shearing action exists, and their diameter shall be such as to provide for a driving fit in the holes. The diameter of the threaded portion shall be at least one-sixteenth ($\frac{1}{16}$) of an inch smaller than that of the shank of the bolt. All threads shall be U. S. standard V-threads. Unless specially noted to the contrary, all bolts shall have standard hexagonal heads and nuts. Lock-nuts shall be provided where there is any likelihood of the nuts becoming loose due to vibration or other causes. Cotters should be used through nuts when it is necessary to hold the latter in a permanent position. Washers shall be provided for all nuts; and where the latter bear on inclined surfaces, special bevelled washers shall be used. Washers shall also be provided where the bolts bear on wood. Bolt heads countersunk in castings shall be square. Wrenches shall be provided for all sizes of bolts; and these shall be part of the operating equipment.

135. *Tap-Bolts*

Tap-bolts shall not be used except by special written permission of the Engineer.

136. *Dust Covers*

Dust covers and safety guards shall be provided for all machinery.

137. *Shims and Drainage Holes*

All machinery, excepting only parts of minor importance, shall be [illegible] on and bolted to the steelwork. Shims shall be provided where [illegible] for aligning and adjusting the machinery, and they shall vary [illegible] by sixteenths of an inch as required.

[illegible] holes of appropriate sizes shall be provided in all machinery [illegible] it is possible for water to collect and stand.

138. *Hand-Operating Levers*

[illegible] levers shall be located for easy access and operation. [illegible] mechanism of swing spans shall be capable of being turned [illegible] as well as from the centre of the span. As many levers [illegible] for the vertical shaft as are required to perform the [illegible]. They shall be about four and a half (4.5) feet above [illegible] levers shall be either of timber or of wrought-iron pipe, [illegible] removable from the shaft. In cases where it is nec-

[illegible] to remove the latter, it [illegible] to engage a square shank on the [illegible] said shaft shall be protected by a

139. Counter

In bob-tailed draw spans the short arm [illegible] as to balance the long arm. The counter [illegible] crete or cast iron placed beneath the floor

In lift spans the counterweight shall con [illegible] concrete blocks at each end of the span. T [illegible] wooden forms on to a steel framework. The [illegible] pended from the equalizers by eye-bars. This [illegible] signed that when suspended from the hangers it [illegible] a block of concrete necessary to form a reinforced [illegible] that it will support the remaining concrete placed [illegible] eral vertical sections, or what is known as the sect [illegible] space of not less than two (2) inches shall be left [illegible] The upper ends of the sections shall be separated [illegible] to the bottom equalizer pins; and guides shall be [illegible] ends so as to hold the sections together in a transv

The counterweights shall be made five (5) per [illegible] figured weight to be balanced; and balancing bloc [illegible] (10) per cent of the figured weight shall be pro [illegible] These blocks shall be made so as to be easily handled [illegible] about one (1) foot on each edge. They shall be [illegible] of ample size for inserting a hook for handling. [illegible] ally be made of three-quarters (¾) inch rods, and [illegible] two (2) inches inside diameter. The blocks shall [illegible] the top of the counterweight and no blocks shall [illegible] of the said wells.

The counterweight shall be guided at the ins [illegible] guides fastened to the steel frame or the concrete and [illegible] attached to the inside of the longitudinal tower [illegible] ance shall be provided in the guides so that they will [illegible] terweight changes its position in moving up and dow

The counterweight shall clear the floor by not le [illegible] when the span has reached its normal lift. In det [illegible] the figured length of the ropes shall be increased by [illegible] stretch in the ropes due to wear, etc. A clearanc [illegible] (2) inches shall be provided between the counterw [illegible] of the tower.

Where it is advisable to provide for a possib [illegible] river channel, necessitating a change in the locati [illegible] tional counterweights formed of pre-cast blocks

tom block shall be designed to carry the upper blocks, which shall be of such a size that they can be readily handled with the equipment that is likely to be available, the heaviest ones weighing in most cases not over two tons each. Their length shall generally be greater than their height, and their width about the same as that of the bottom block; and they shall have their inner contact surfaces beveled so as to produce a wedging effect when placed in position, thus assuring a tight fit. The blocks shall be provided with ample U-bolts for handling. Provision for adjusting the weight shall be made in the same manner as for solid counterweights. This same type of counterweight shall be adopted where it is desirable to cast the blocks on the ground and hoist them into place, even though the span be not designed for shifting in the future.

The counterweight shall be made of either stone or slag concrete. As a rule, stone concrete shall be used. It shall be assumed to weigh one hundred and forty-seven (147) pounds per cubic foot, exclusive of the steel. Slag concrete shall be assumed to weigh one hundred and seventy (170) pounds per cubic foot. In every case the approximate weight of the concrete to be used shall be ascertained before designing the counterweight.

In bascule spans the counterweight shall be of either concrete or cast iron, depending on the type of bascule under consideration. The concrete counterweights may be attached rigidly to the steelwork, or pivoted, depending, as before, on the type adopted.

140. *Machinery House*

In swing bridges and vertical lift bridges the machinery house shall usually be placed at the centre of the span, and in bascule bridges where most convenient, depending on the type of bascule adopted. The house shall generally be of fireproof construction, although in certain cases, where the danger from fire is very remote or where the money available for the structure is small, timber construction may be employed. The fireproof construction shall consist of a steel framework and floor system with the walls and floor of concrete, steel plates, or other non-combustible materials. In the timber construction steel floor-beams shall be used.

The house shall be of such size that there will be ample room for the machinery, work-bench, stove, and chair, and to provide easy access to all parts of the said machinery. Wherever shafts are located above the the floor, stiles shall be provided for crossing over them. The house shall contain ample window space so as to provide as much light as possible as well as to permit the operator to watch the traffic on both the bridge and the river. The windows shall be of a single pane in each sash. The house shall be made weatherproof; and where gears or other machinery project below the floor, the openings thus made shall be boxed in. In cold climates, especially when the operator has to remain within it con-

[illegible] by hand operation is [illegible]
[illegible] amply large to permit the [illegible]
[illegible] construction, as the floor of the [illegible]
[illegible] the structure is of sufficient [illegible]
[illegible] a five (5) ton crane running on [illegible]
shall be provided in the house.

141. Walkways

Stairs shall be provided for access to both
the machinery house, and walkways for
of the latter.

142. *Operator's*

In case the operator is not located in the
ator's house shall be so placed that he can have
all directions of the traffic on both the bridge
shall be of the same construction as that
house; and it shall be of ample size to
the controllers, levers, switchboard, indicato
equipment needed by him. The house shall
window space.

143. *Gates*

Gates of substantial design shall be furnished
of all movable bridges for highway traffic.
and built of structural shapes. There shall be
end, swinging on pivots near the trusses. They
two of the gates can be closed to the oncoming
closed after the movable span has been cleared
gates shall be controlled either by the operator or
provided for the purpose. The gates shall be
of lock or stop to hold them in both the closed

144. *Gate Tender's*

Gate tenders' houses shall be furnished
for the convenience of the gate tender. They
tion so as to conform to the general surroundi
shall be of timber or, preferably, concrete
provided with stove and chair.

145. *Boat Indicator*

On one leg of the tower, on both the upstream and the downstream sides, and extending down on the pier to low water level, a gauge shall be painted in large figures for the convenience of the river traffic. An indicator at the lowest point of steel of the lift span shall show to the occupants of passing vessels the height on the gauge to which the span has been lifted. By noting the gauge reading at the water level one can ascertain readily the height of the span above the water.

CLAUSE INDEX OF CHAPTER LXXVIII

CHAPTER LXXIX

GENERAL SPECIFICATIONS GOVERNING THE MANUFACTURE AND ERECTION OF THE SUPERSTRUCTURE, SUBSTRUCTURE, APPROACHES, AND ALL ACCESSORY WORKS OF BRIDGES, TRESTLES, VIADUCTS, AND ELEVATED RAILROADS

Some five years or more ago, in order to be prepared for any case of contract letting that might arise, the author undertook to draft for his firm seven sets of specification forms for the use of the office so as to enable the principal assistant engineers to aid in writing specifications for the current work; because up to that time all such documents had been prepared personally by one or other of the two members of the firm, and the task had become almost unbearably onerous in view of the fact that the bridgework under way in both office and field amounted in value at times to twelve and even fifteen millions of dollars. The seven sets of specifications mentioned were the following:

1. Manufacture of Superstructure Metal.
2. Manufacture and Erection of Superstructure.
3. Substructure.
4. Substructure and Erection of Superstructure.
5. Substructure, Manufacture of Metalwork, and Erection of Superstructure.
6. Erection of Superstructure.
7. Reinforced Concrete Structures.

After all these were finished, their mass (involving many hundreds of typewritten pages) was so appalling that it was decided to combine them into one document. In making the combination it was the intention to cover every feature of bridge building that had ever occurred or would be likely to occur in the firm's practice, including substructure, superstructure, approaches, and accessory works. This was done by the author personally; and from time to time he has since added a few clauses bearing upon questions that have arisen in the firm's operations. The final compilation is herewith presented in the hope that the reader may be able to use it in exactly the same manner as did the few of the firm's assistant engineers who were entrusted with the duty of specification writing.

It will be noticed that some of the clauses are complete and permanent. These are marked "P." Some are variable and are marked "V," and others are incomplete and are marked "I." In the case of each

[illegible] (o[illegible]
[illegible] of what the clause should
example taken from the author's practice,
[illegible]. The "incomplete" [illegible]
[illegible] be filled in so as to make them
[illegible] words appear in bold-faced type; and
be omitted or modified in many cases.
the words Contractor, Engineer, etc., in the

The order in which the various items are
respect to continuity as it could be made,
ceding the one that follows, and the direc
specified being grouped to a certain extent in

To use the form in preparing the specifications
whole or any part of any particular bridge, one
item and go through the entire list to the end,
filling out the incomplete ones and copying the
omitting, however, all those which are not applicable
By so doing the writer will ensure that nothing of
ted, that his clauses are in fair sequence, that there
that his resulting specifications will cover the whole
and satisfactorily, provided, of course, that he
and possesses the ability necessary to do such
writing of bridge specifications.

At the end of this chapter is given an alphabetical
clauses which it contains, referring to them by their
inserted for the convenience of any reader who
chapter in the preparation of some particular
addition, however, the contents of the chapter are
the general "Index" at the end of the second

After the manuscript of this chapter was
date, the author's attention was called to the paving
American Society of Municipal Improvements for
vinced that there exists no higher authority on
ciety, he decided to modify certain of his paving
with its requirements, quoting in certain places
and making but few modifications.

SPECIFICATIONS

V. 1. *Location*

This clause should give for each structure the
street, railroad, etc., to be crossed and the name
in (or near) which it is located; also the county
located in a country district, give the name of

[illegible] state the district it is, also in what direction therefrom the site lies. If the structure be a railroad bridge, give the name of the railroad company; but, if not, state for whom it is to be built. State whether the bridge is to replace an existing one, and, if so, who will remove the old structure, and when. If it be a city bridge, state the name of the street it is to occupy.

EXAMPLE

The two bridges are about nine miles apart on the extension of the line of the Louisiana and Arkansas Railway in Catahoula and Concordia Parishes, Louisiana. The nearest railroad station at present is Black River Station, on the line of the St. Louis, Iron Mountain, and Southern Railway. The bridge over Black River is about one mile downstream, and that over Little River about ten miles upstream from this station.

V. 2, *General Description*

For the superstructure there are two types of general description to be employed, viz.:

- A. When complete detail drawings accompany the specifications, and
- B. When bids are called for in advance of the preparation of the complete detail drawings, in which case either special typical show drawings are prepared or old drawings of somewhat similar structures are offered as samples or guides to bidders in the determination of schedule prices for their tenders.

In "Type A" very few dimensions should be given in the specification. All that are necessary are the ruling ones, such as span lengths and perpendicular distances between central planes of trusses, or clear widths of roadways and sidewalks. No minor dimensions, such as sizes of stringers, weights or dimensions of handrails, or sizes of guards, should be given; for these can be obtained from the drawings. All descriptions, such, for instance, as those of operating machinery, should be very brief; but they should be ample enough to give the reader a clear idea of what the part described is like. This clause should indicate in a general way the characteristics of the construction.

In "Type B" the description should be gone into in very thorough detail, giving the number and sizes of all important parts, but taking care to indicate that the dimensions are either merely approximate or subject to change, in order that later, if modifications be desired, no reasonable objection to their being made can be raised by the contractor. Each [illegible] span in the design should be described separately, giving its length, the character of the construction (whether riveted or pin-connected), the [illegible] lengths of panels, the truss depth, the perpendicular distance [illegible] central planes of trusses, the number, kind, and sizes of stringers [illegible] the method of providing for expansion and contraction, the [illegible] in towers, the method of attaching longitudinal girders

column tops, etc., referring,
drawing that illustrates the feature
described fully; and in connection with
they are to be furnished at the same average
structure metal, in order to forestall a
tractor for a higher schedule price, on the
extra for metal hand-rails. In case there are
travel when the moving span is to be opened,
should be fully described in this clause so as to
same anywhere else in the specifications.

The machinery should receive particular
likely to be different in many ways from the
It should be described systematically in all its
the horsepower should be stated within fairly
motors, etc., being taken per horsepower. If
be provided in addition to mechanical power, this

In case of a lift span or other movable span
a complete description of its construction and mode
be given.

The machinery house or houses should be
bidders can tender intelligently thereon either by
rates, according to whichever method of receiving
work has been decided upon by the Engineers.

In case that the structure is arranged for future
addition of roadways or sidewalks outside of the
pointed out and the method of future attachment
mark applies equally to both types of specifications.

The flooring or pavement of both the main roadway
the guard angles, the system of lighting the structure,
pavement, the provision for expansion and contraction,
column feet of viaducts by cast-iron fenders filled with
ing, the railway rails with their splice-bars, bolts,
spikes, the trolley poles and wiring, and the timber,
untreated, should be fully described.

If the contract is to cover the approaches to the
be accurately described in complete detail, omitting
portance. Ordinarily, if the approaches be of timber,
to the superstructure contract, but if of concrete
they will pertain to the substructure contract.

For the substructure of bridges this clause should
tion in the following order:

First. Layout of spans and piers, referring
drawings.

Second. Character of the materials to be
dations to be reached.

Third. Method of sinking cribs or caissons.

Fourth. Characteristics of piers, pedestals, and abutments.

Fifth. Earth embankments or filling, if the same be included in the contract.

Sixth. All characteristics and special features of the crossing not specifically treated in other clauses.

For reinforced concrete bridges the directions are the same as for substructure, except that the fourth item thereof should read thus:

Fourth. Characteristics of spans, arches, piers, abutments, hand-rails, pavements, guards, sidewalks, cross-walls, ornamentation, drainage, provision for expansion and contraction, railway rails (with their splice-bars, bolts, tie-bolts, ties and spikes), lighting, and trolley.

In giving the data for substructure, if any thereof have to be verified by bidders, attention should be called as to which items of information are and which are not to be verified. For instance, it would not be right to ask bidders to check the results of the borings; but it would be perfectly proper to place on them the onus of verification of the locations of sand and gravel beds, the qualities of the materials to be found therein, the length of haul and the condition of the roads, the availability of suitable stone for rip-rap, and similar information given in the specifications.

It must be borne in mind that the more complete the data submitted to bidders, the more accurately they can make their estimates, and the lower, consequently, will probably be their tenders.

EXAMPLE FOR SUPERSTRUCTURE

The bridge over the Black River is to consist of five (5) through-truss, riveted, single-track, railway spans, each one hundred and sixty-five (165) feet long, supported on six (6) piers. One of these spans is arranged to be lifted between two towers, supported on the two adjacent spans, to a height sufficient to allow for the passage of river traffic. The lifting span will be suspended by eight (8) wire ropes at each corner, which pass up and over sheaves at the tops of the towers and are connected to two (2) counterweights of concrete and steel, exactly balancing the span. The operating machinery, which is carried on top of the lifting span at the [illegible] consists of four spirally-grooved drums, actuated through trains [illegible] by gasoline engine. Each drum controls two operating ropes; [illegible] at the top leads over a sheave at the corner of the span, thence [illegible] and is fastened near the bottom of the tower; the one from [illegible] of the drum leads under the same sheave at the corner of the [illegible] upward, and is fastened at the top of the tower. All four [illegible] similarly connected, and when they are revolved in one direc[illegible] leading to the tops of the towers are wound on, and those [illegible] the bottoms of the towers are payed off, thus raising the [illegible] force exerted on the corner sheaves. Reversal of di-

The span

emergency.

The bridge over the Little River is to ated, single-track, railway spans, each One of these spans is likewise towers supported on the other two spans. and operated as described for the Black River

EXAMPLE FOR SUBSTRUCTURE

The bridge, the substructure of which is to be will carry two standard railway two street car tracks in a paved roadway and two deck. The railway tracks approach the a fifteen-degree curve, which extends over two and ends on the westerly main channel span; to a point about two-thirds of its length span, where they turn out in both directions on

The street railway and highway approach at the easterly side of Third Street and is carried, then on a steel trestle parallel and immediately thence across the river on the upper deck of the and thence on steel trestle to its easterly end and Adams streets.

The substructure required consists of the and seventeen pedestals for the westerly street proach, an abutment and a pier for the westerly westerly shore pier, two mid-river piers, and an port the main channel spans, and ten pedestals and easterly street railway and highway approach.

The bases of both end abutments and all next the westerly shore, are near or above the they may be constructed in open excavations. The abutment, and the two piers next the westerly shore piles, and excavations for them will be made dredging. The two main channel piers will be ing process to a bed of cemented gravel lying twenty to one hundred and thirty feet below ment at the easterly shore will rest on a bed of found but ten to twenty feet below low-water constructed of concrete with granite caps. The concrete with granite bridge seats, and the walls for the westerly approach will be of

Remarks for Reinforced Concrete Bridge

The structure consists of 8 reinforced concrete arch spans, each [illegible] feet long in the clear, or 118 feet 9 inches from centre to centre of piers, the total length between springing lines at abutments being 941 feet [illegible] inches. Three of the piers will be supported on piles, which are to be driven by water-jet, as described herein. The other four piers are to be carried to bed-rock. The concrete shaft of each pier rests on a mass of concrete below low-water level, which mass is enclosed in a box composed of 12″ × 12″ timbers encasing the heads of eight rows of piles, as shown on the drawings, where piles are used beneath the piers. The length of the piles there indicated is thirty feet, but the actual length to be used cannot be determined except by trial. The Contractor will be required to put in as long piles as can be driven by water-jets and hammer combined without involving unusual difficulty and expense. He will be paid for the cut-off ends according to the terms of the clause for "Unclassified Work." The depths to which all piles are to be driven will be determined solely by the Engineers.

As there is to be no direct payment for the timber bases of the piers, the Contractor will be at liberty to use sheet piling instead, provided the Engineers deem this satisfactory. Unless the Engineers decide that so doing would injure the foundations, the sheet piling may be withdrawn; but in such cases the voids thus left must be filled with small broken stone or tamped gravel in order to avoid inducing scour.

The main dimensions of all piers and abutments are shown on the accompanying drawings.

On the top of each pier, immediately below the arches, is a coping surmounted by a cocked hat at each end, and above this is a narrow ornamental wall which appears to be a continuation of the pier. Above the arches, which are 24 feet 6 inches wide, rise narrow transverse walls to [illegible] the floor.

The main roadway, which is ultimately to carry a double-track electric railway, is 30 feet wide in the clear; and on each side of the bridge [illegible] sidewalk 5 feet wide in the clear, which, with a portion of the [illegible] cantilevered out beyond the arches and cross-walls by beams [illegible] concrete. The end arches of the bridge spring from con[illegible] of the type shown on the drawings. The face of the [illegible] the city will lie in the same plane as the face of the retaining [illegible] already constructed. A cheap concrete backing will be used [illegible] in order to increase their mass so as to resist properly [illegible] the arches.

[illegible] support a slab of reinforced concrete, upon which is a [illegible] to carry the concrete base for the block pavement, all [illegible] drawings. The railroad tracks will not be put on at

present. The block pavement will be
cantilever brackets of the sidewalk is a slab
ing a mass of sand, upon which rests the
the latter and the lower slab is space that may
pipes, gas pipes, or telephone conduits, as indi
The hand-rails are to be of concrete of an orname

V. 3. *Changing of Grade*

The grade of the new structure is to be . . . . . .
than that of the present bridge; and the Contractor
field operations that the changing from the old to the
interfere materially with traffic.

V. 4. *Temporary Bridge*

Sometimes it is necessary that the Contractor buil
or trestle to take care of the traffic before beginning
bridge. In such a case there should be here given a
tive, general specification for the said temporary b
the detail specifications for its construction need no
clause, because they will be found farther on in the
building temporary structures it is often permissible
second-hand materials, and to what extent this may
made clear in this clause. Again, for temporary work
to protect the wood against decay as specified for
constructions. Should any job be divided among two o
the duties of each in connection with the temporary
clearly defined.

EXAMPLE

As shown on Drawing 19, it will be necessary to bu
connecting the ends of the present draw span with the
trestle on the east end and with Eleventh Street and Cl
west end, in order to maintain traffic during the const
bridge.

The present structure consists of two fixed spans
over the waterway, and a steel trestle or viaduct at the
connected. The contractor for the substructure shall
piers and the pier between the draw pier and the west
bridge; and he shall remove the two fixed spans and
west end of the bridge. The swing span will be swu
to connect to the ends of the temporary wooden tre
for the substructure shall also furnish all materials f
maintain during the continuance of his operations the
trestle, and thus maintain traffic on Eleventh St
timber trestle at the east end to Cliff Avenue at the

The contractor for the erection of the superstructure shall remove the draw span and the pier supporting it and the draw protection; and he shall maintain the temporary trestle from the time the substructure contractor has been relieved of that duty by the city; then he shall remove the temporary trestle, the materials in which shall become his property.

V. 5. *Removal of Old Structure*

It often occurs that the Contractor has to take down the old spans and even remove the old piers. In such a case a complete specification for such removal should be drawn, and in it should be clearly stated what is to be done with the old materials and who is to do the various handlings thereof. Again, it should be made clear who is to be the owner of the old materials. Sometimes it is better to let the Purchaser keep either the whole or a portion of them, but at other times it is better to let all of such materials become the property of the Contractor. In the latter case care should be taken to specify where he can and where he cannot store them, and how long they may be left at any place where stored temporarily. In the case of old wrought-iron bridges the metal is useful and valuable for blacksmith work, but old steel is good for nothing but scrap. Old masonry can often be employed for rip-rapping piers on pile foundations. Old timber may be valuable for falsework, or other construction, but generally it is fit only for firewood. Before settling what is to be done with the old materials the Engineers should consult their principal, the Purchaser, and obtain his decision on the matter. If the old superstructure is to be re-erected, this clause should specify how it is to be match-marked, paint-marked, piled, and loaded so that the metal may be properly kept track of for future use.

In respect to the removal of old piers and abutments, the elevation or elevations to which they are to be taken down should be stated; and it should also be made clear whether the piles are to be drawn or to be cut off at a certain elevation.

EXAMPLE

The old masonry abutments shall be removed to one foot below ground surface, and such parts of the material as the engineers may designate shall [illegible] placed in dry walls at the foot of the embankments. All other materials [illegible] old bridge, except the metalwork and bolts, are to be the property of [illegible] Contractor. The old steel span is to be match-marked and carefully [illegible] down; and all parts thereof, together with all bolts in the timber [illegible] to be stored in an orderly manner at a point on Troost Avenue [illegible] feet of the bridge, in accordance with the directions of the [illegible]

V. 6. *Remodeling of Substructure*

[illegible] the Contractor is required to remodel the tops of old piers, [illegible] to lower them or to strengthen them so as to carry

[illegible] for tearing down the old [illegible] as the Engineers deem preferable. [illegible] masonry that is left in should be considerably [illegible] the pier tops with concrete should be fully [illegible] advisable to strengthen the new tops of the old [illegible] rails in them, which rails are the property of the [illegible] case the conditions governing the obtaining and [illegible] should be thoroughly explained in this clause, [illegible] when, and where the said old rails are to be [illegible] and what he is to do with them after they are so [illegible]

EXAMPLE

Nine masonry piers for a high-level bridge [illegible] several years since. The bridge to be built now [illegible] deck type, having the lower deck at a much lower [illegible] plan provided; and the grade of the upper deck [illegible] on the original plan. Therefore it is necessary to [illegible] bridge seat by building up the masonry on some [illegible] on others by removing the tops of the piers; and [illegible] girders will be placed in the tops of the piers to [illegible] the load.

The work to be done under this contract is as [illegible]

A. Build three concrete abutments, one on [illegible] Street and one on the south side of First Street.

B. Place in the position and elevation required [illegible] and II, steel girders, which the Company will furnish, [illegible] about the girders with quarry-faced masonry, and fill in [illegible] the girders with rubble masonry or concrete, all as [illegible] Drawing No. 57.

C. Build up Pier III with quarry-faced masonry [illegible] rubble masonry backing, as shown in outline on [illegible]

D. Remove the tops of Piers IV and V, replace [illegible] masonry, and place in the new tops of the piers steel [illegible] Company will furnish, all as shown in outline on [illegible]

E. Remove the tops of Piers VI and VII and [illegible] of masonry, as shown in outline on Drawing No. 55, [illegible] will be required in these piers.

H. Remodel Pier VIII, situated on the south [illegible] railroad tracks, substantially in accordance with [illegible] location of the north approach should be changed, a [illegible] pair of large concrete pedestals shall be constructed [illegible]

I. Remodel Pier IX, situated on the north [illegible] railroad tracks, as noted on Drawing No. 61, [illegible]

[illegible] masonry with rubble or concrete backing, in order [illegible] ment for the earth fill in the north approach.

Build or alter any other masonry for the bridge that the Com- may desire built or altered.

he materials to be removed from the present piers shall remain the rty of the Company. The Contractor shall use in the remodeling he present and in the construction of the new masonry such portions he stone removed from the present piers as the Engineers may deem able; and the remainder of the materials removed from Piers IV, VI, and VII shall be deposited on the Company's property where the gineers direct. The unused materials from Pier VII shall be placed the north side and those from Piers IV, V, and VI on the south side the river.

The existing piers are to be remodeled as above described and as own on the drawings. All the rebuilding is to be done in a truly first- manner and to the satisfaction of the Engineers. In removing the nes care is to be taken not to injure in any way either the pier or any the stones that are to be utilized in rebuilding.

V. 7. *Remodeling of Superstructure*

Occasionally it becomes necessary, in replacing an old bridge, to retain portion of the superstructure. In such a case a full description, with wings, should be prepared for such replacement, and detailed directions should be given concerning its *modus operandi*.

EXAMPLE

The work of remodeling the superstructure of this bridge consists of he following:

A. Building falsework under each span so as to support it and carry trains during the reconstruction.

B. Removing and replacing certain vertical posts and diagonals as marked on the accompanying plans.

C. Strengthening the floor-beams by adding cover plates to the top bottom flanges.

D. Doubling the stringers.

E. Removing and replacing the portal bracing.

F. Painting all new metalwork.

G. Removing of débris.

the work to be done is indicated clearly on the accompanying plans, show perfectly which is new construction and which is old. The lwork is to be manufactured in strict accordance with these [illegible], and is to be put in place in a manner satisfactory to the [illegible]. All fieldwork is to be conducted in accordance with the these specifications for new work.

[illegible]

V. 8. *Furnishing of*

In some cases certain materials, such as
bolts, and rail-spikes, are to be furnished by
place by the Contractor. Under such conditions
with either a general heading like the above or a
tion to the particular material to be furnished.
that the Contractor must receive, haul, and store
responsible therefor until the completion of the

EXAMPLE

The Railroad Company will furnish the Contractor
at Sunshine Station all the cement required for the
tractor must receive, unload, haul to site, and store
use; and he will be held responsible for its being
until then. The Contractor will be allowed three (3)
empty each car of its load of cement, after which
usual demurrage.

V. 9. *Maintenance of Traffic*

In reconstructing an old bridge it is almost always
tain the traffic crossing the structure as well as to
ference with other traffic indirectly affected by the
gable waterways, public highways, private rights-of-way,
a structure, cannot be obstructed except by special
by the proper authority; and, as a rule, it is necessary
erection without such interference. This is also true
This clause should state the kinds of traffic to be dealt
cautions to be taken in each case.

EXAMPLE

The Contractor must so conduct all of his operations
to the least extent practicable with the passage of
trains, vehicles, animals, pedestrians, and all other kinds
and he must take every precaution against accidents
said boats, rafts, trains, vehicles, animals, pedestrians,
because of his operations. No thoroughfare of any kind
without the written consent of the proper authorities

V. 10. *Maintenance of Sewers and*

In constructing a bridge existing water-pipes,
have to be moved or temporarily supported. This

who is to perform this work, and whether there is to be any direct payment therefor.

EXAMPLE

Unless otherwise agreed upon in writing, the Contractor shall maintain and leave in good condition any sewers, pipes, or other conduits uncovered or disturbed by his operations; and, if necessary, he must remove the old ones and build new ones. Such removal and building shall be treated as "Unclassified Work," unless there be schedule prices to cover them in the Contractor's tender, or unless some special agreement for the work involved be entered into by the Contractor and the Purchaser (either personally or through the Engineers).

V. 11. *Side-Tracks*

In this clause there should be stated what facilities exist for building side-tracks for unloading materials, who is to build them, and at whose expense. Generally the railroad company puts them in at its own expense and removes them after the work is completed; but sometimes the Contractor has to put them in either at his own expense or at that of the Purchaser.

EXAMPLE

The Purchaser will furnish the Contractor with all the rails, switches, angle-bars, bolts, spikes, and ties required for building 2,450 lineal feet of side-track; and the Contractor will be required to do the necessary grading and lay the track. After the structure is completed the Contractor, at his own expense, is to take up and store at Walhachin Station, as directed by the Purchaser, all the said track material and leave the same in good order.

V. 12. *Storage Facilities*

In this clause should be stated what storage facilities exist or may be had in the neighborhood of the bridge site; and if the Engineers know what the cost thereof would probably be, they should state it, but at the same time they should make it clear that the Purchaser is not to be held responsible for the correctness of the statement.

EXAMPLE

It will be necessary to build a short, temporary track from the site close to low-water line around to a small flat lying between the site and the town of Lytton. This ground is somewhat broken, and is by no means ideal for storage, but it is the best that can be had. As it is useless for cultivation, being covered with boulders, there will probably be no charge for rental. However, the Purchaser does not guarantee this.

[illegible]

The Government records show that the [illegible] the months of August, September, and October, [illegible] due to tide reaches approximately two feet [illegible] high-water season the effect of tide is negligible [illegible] spring high waters are usually from the upper [illegible] companied by considerable current; but the [illegible] ordinarily back water from the Columbia River [illegible] specifications is a chart showing the record of [illegible] by the U. S. Government.

In preparing his tender each contractor is to be [illegible] judgment of probable river conditions; and the actual [illegible] will in no way be considered as unforeseen.

V. 14. *Transportation over Purchaser's* [illegible]

In this clause should be stated whether men, [illegible] or are not to be hauled free of charge over certain [illegible] lines that are owned or controlled by the Purchaser.

EXAMPLE

The Purchaser will haul both ways, free of charge, [illegible] tractor's men, materials, and plant which may be [illegible] or indirectly in connection with the work covered in the [illegible] following lines of railroad. . . . . .

V. 15. *Engine Service*

In this clause should be stated whether the Contr[illegible] engine service free of charge or, if not, how much [illegible] for each engine with its driver and stoker. Generally [illegible] the Contractor pay the Purchaser for engine service, [illegible] keeping the engine and crew hanging around idle [illegible] Contractor to finish portions of the work. On the [illegible] every part of a day occupied should count for a [illegible] unoccupied portion would probably be wasted by [illegible]

EXAMPLE

The Purchaser will furnish the Contractor, at the rate of........... dollars ($........) per day, engine service (including one locomotive, one driver, and one stoker, with fuel, oil, waste, and all such supplies) for placing cars to unload material, for taking down, transporting, and storing of the metal of the old structure, and for moving plant and materials for the new work. Each portion of a day that an engine and crew are employed shall be paid for as a whole day.

V. 16. *Routing of Freight*

In this clause should be stated by what railroad or railroads the materials are to be transported, provided that the favored route is no more expensive to the Contractor than any other. It is only occasionally that this restriction is placed in bridge specifications; but when their principal is a railroad company, the Engineers should always ask whether there are any instructions to be given concerning the routing of freight.

EXAMPLE

Provided the Contractor be put to no extra expense thereby, the metal is to be shipped from Pittsburgh to St. Louis by the Pennsylvania System, from St. Louis to Texarkana by the Missouri Pacific System, and from Texarkana to destination by the Kansas City Southern Railway Company.

V. 17. *Customs Duties*

When the metal work or other material is to be delivered in a foreign country, the specifications invariably should state who is to pay the customs duties.

EXAMPLE

The prices named in the Contractor's tender must cover the customs duties on all imported materials and plant used in the construction of the bridges.

V. 18. *Patents and Royalties*

When any patented articles are to be used on the work, the specifications invariably should state who is to pay the royalties thereon.

EXAMPLE

With the sole exception of any patents that may be owned or controlled by the Purchaser's Engineers, the Contractor is to pay all royalties charged for the use of patented articles employed in manufacturing or building the structures.

V. 19. Observance

The Contractor throughout his
laws and restrictions of the City, County,
is being done, and must hold the Purchaser
penalties incurred by the Contractor for the
restrictions.

(N. B.) In certain cases the preceding
others it is better to be more specific, thus:

EXAMPLE

The Contractor shall not employ on the work,
rectly, any Asiatic or any person of the Asiatic

No work whatever shall at any time or place
necessity when danger to life or property is involved
Sunday, and the Contractor shall take all necessary
any foreman, or agent, or workman, or other
employing others on that day. The Purchaser shall
responsible for any infraction by the Contractor of
labor restrictions.

I. 20. *Limits of Daily Labor*

The Contractor shall not employ upon the
therewith any workman or employee for more than. . .
per day of twenty-four hours. The working day shall
o'clock, A.M. and shall end at . . . . . . o'clock P.M. If
men are working in one day, the same men shall
work on more than one shift. Overtime shall not be
pretense whatever, except when human life is in
erty is in danger of destruction. In such cases
until the work is secured from danger, but no longer.

I. 21. *Rates of Wages*

The Contractor shall pay or cause to be paid to any
mechanics, or laborers, employed by him on or in
work, a rate of wages not less than that generally
. . . . for competent workmen, artisans,
when employed on similar work.

V. 22. *Sources of Supply for*

It often helps bidders in preparing their
fications a clause stating where many of the

r the work may be obtained conveniently; but it is well to give, if possible, a choice of places so as to prevent monopoly and its consequent excess expense to the Purchaser.

Example

Good, clean sand can be found in a bank about three-quarters of a mile from the bridge site; and there is a fairly good road with a continuous down grade from the said bank to the site. Gravel of satisfactory character is obtainable in large quantities from a bar about half a mile up-stream, but it will require washing. Broken stone can be brought in by rail from a quarry ten miles distant, but will have to be transported by wagon a full mile from the railway station. There is no local timber available, hence what is needed will have to be brought from the coast by rail.

V. 23. *Prices of Materials*

It is often advisable to state the prices at which the materials required r construction can be bought, but as a matter of precaution no responsibility to the Purchaser or the Engineers should be assumed by making the statement.

Example

The following prices of materials, delivered on cars at various stations of the Purchaser's line, are furnished to bidders as a guide in preparing their tenders; but it is understood that the Purchaser in no way guarantees their correctness:

Portland cement	$1.65 per bbl.
Long-leaf yellow pine timber	18.00 per M. ft. B. M.
Short-leaf yellow pine timber	15.00 per M. ft. B. M.
Long-leaf yellow pine piles	.08 per lineal foot
Oak piles, from 30 ft. to 40 ft. long	.15 per lineal foot
Gravel	.50 per cu. yd.
Sand	.25 per cu. yd.

P. 24. *Spirit of the Specifications*

nature and spirit of these specifications are to provide for the herein enumerated to be fully completed in every detail for the purdesigned; and it is hereby understood that the Contractor, in acceptcontract, agrees to furnish any- and everything necessary for such on, notwithstanding any omission in the drawings or specifi-

V. 25. *Modus Operandi of Construction*

operandi of construction has been laid out in advance, the should be adopted:

[illegible] of the Contractor.”

But if there is determined in [illegible] ce, it should be given in detail, [illegible]

[illegible]

[illegible] **Example** [illegible]

On account of the short duration of the [illegible] of pneumatic piers will have to be [illegible] of the river about the first of September and [illegible] of January. Two full pneumatic outfits [illegible] will have to be pushed with the utmost [illegible] brought above extreme high-water level before the [illegible] tion of the shaft ceases temporarily. As the [illegible] high water, has no great velocity of current, [illegible] the completion of the shafts during the [illegible]

It will not suffice to delay the construction [illegible] of the approaches until the high-water season, [illegible] sary to start the erection of the said approaches [illegible] thereof. Moreover, as the approaches are to be [illegible] the metal of the main spans to the river bank, and [illegible] the greatest haste in the completion of the structure, [illegible] to start the erection of the approaches simultaneously [illegible] so as to complete them by the time that the river [illegible]

V. 26. *Accompanying Drawings* [illegible]

Give in some systematic order a list of all the [illegible] pany the specifications, and state whether these are [illegible] plete detail drawings to be furnished by the Engineer, [illegible] indicate which are specially prepared for the contem[illegible] and which are drawings of old, similar structures [illegible] samples of what the work will be like. This is [illegible] anticipate the Contractor’s possible claim for extra [illegible] on the plea that the actual work has differed from that [illegible] bidding drawings.

Example

The following drawings accompany and supplement [illegible]

General and Substructure Drawings and Stress Sheets [illegible]

1. General Plan and Profile, Black River Bridge. [illegible]
2. General Plan and Profile, Little River Bridge. [illegible]
3. Location Map, Black River Bridge.
4. Location Map, Little River Bridge.

5. Substructure, Black River Bridge.
6. Substructure, Little River Bridge.
7. Diagram of Stresses and Sections, Black River Bridge.
8. Diagram of Stresses and Sections, Little River Bridge.

Typical Detail Sheets

10. Counterweights, City Waterway Bridge.
13. Floor System 201-ft. Span, Keithsburg Bridge.
14. Trusses 201-ft. Span, Keithsburg Bridge.
24. Trusses, 114-ft. Span, Keithsburg Bridge.
29. Details of Towers, Keithsburg Bridge.
30. Details of Towers, Keithsburg Bridge.

Machinery Drawings

M1. Tower sheaves, shafts, bearings, equalizers, ropes, and rope sockets for Black River Bridge.
M2. Tower sheaves, shafts, bearings, equalizers, ropes, and rope sockets for Little River Bridge.
M3. General arrangement of operating machinery for Black River and Little River bridges.
M4. Mechanical Indicator for Black River and Little River bridges.
M5. Guide Rollers for Puyallup River Bridge (illustrative for guide rollers).
26. Centring Castings for Keithsburg Bridge (illustrative for thrust castings).
41. Rail Locks, Keithsburg Bridge (illustrative for rail locks).

Nos. 1 to 8 inclusive and M1, M2, M3, and M4 have been prepared specially for the two proposed bridges; but the others are offered merely to show the character of the details, in order that bidders may tender on the work at unit prices.

V. 27. *Detail Drawings*

If the complete detail drawings are not submitted to the bidders, the following clause is to be used under this heading:

"As soon as practicable after the contract for building the structure is signed, the Engineers will furnish complete detail plans, in strict accordance with which the Contractor shall prepare his shop drawings or his working drawings."

Sometimes, however, it is advisable to state exactly when the drawings will be ready.

V. 28. *Working Drawings*

The wording of this clause will depend on the type of structure to be built. It should fix the responsibility of the Contractor in regard to the checking of the Engineer's plans, should determine the plans to be pre-

pared by the Contractor, should
and revising them after they are
ing of plans and the compensation for
becomes necessary to make alterations
should specify the plans that are to be furnished

EXAMPLE 1

No alterations shall be made in the
the written consent of the Engineers. The
check the Engineers' plans before beginning the
ing drawings, and should any errors be found
attention of the Engineers, who will make the
which the Contractor shall be responsible for all
or which may have occurred. The Engineers shall
the plans as they may see fit, if further
affecting the structure should so warrant; and they
make minor changes in all plans during fabrication,
charge for the same being made by the Contractor,
the Engineers, the Contractor be really entitled to
account of such changes. If practicable, the
pensation shall be agreed upon in writing by the
tractor before the unanticipated work is started.

The working drawings shall be sent in duplicate
the Engineers, who will retain one set and return the
them and marking thereon any changes or corrections
such changes or corrections are necessary, the drawings
and prints again sent in duplicate to the Engineers;
be continued for any drawing until the Engineers
Contractor an approved print thereof. As soon as
of any drawing has been received by the Contractor,
send to the Engineers as many additional prints as
Should revisions in any drawing be made at any
shall send to the Engineers for their approval two
the said revisions plainly noted thereon, and shall
additional sets of duplicate prints until the approval
the revised drawing is obtained. After the said revised
finally approved, the Contractor shall at once send
many additional prints thereof as they may require.
the progress of the work, the Contractor shall furnish
many sets of working drawings as the Engineers and
Purchaser may desire.

Should the Engineers prepare any working
carefully checked by the Contractor; and if any
the Engineers' attention shall be called thereto.

tions of these are made, the Contractor shall be responsible for all errors which may occur or which may have occurred.

With his working drawings the Contractor shall furnish an erector's diagram which shall show clearly the marking and position of each member of the bridge, also a camber diagram.

Upon the approval of the working drawings, but not before, work on the structure may be begun; and it is expressly provided that such approval shall in no way release the Contractor from responsibility for drafting or shop errors. After the plans have been approved, alterations will be permitted only upon the written instructions of the Engineers.

The Contractor shall prepare complete detail plans showing shape, dimensions, and position of all reinforcing bars, and shall design and prepare full working drawings for all forms, falsework, and staging, and for all erection equipment; and these drawings must be made to meet the approval of the Engineers before construction begins.

Before the constructions are accepted, the Contractor shall furnish to the Purchaser, without charge, one complete set of all shop drawings and all working drawings printed on cloth.

EXAMPLE 2

The Contractor shall prepare all detailed working drawings required to enable him to fabricate, erect, and construct all parts of the work in strict conformity with the Engineers' drawings and with these specifications.

These working drawings for structural steel and machinery shall include, in addition to the necessary shop drawings, camber diagrams and erection diagrams which show clearly the marks and position of each member.

For reinforced concrete construction, the working drawings shall show the dimensions, shape, position in the work, and means of supporting in position of all reinforcement, and all forms and the means of supporting them.

For substructure and all general construction the working drawings shall show all minor and special details which are left open to the Contractor's choice of methods of construction or which for any reason are not fully shown on the Engineers' drawings.

For all construction the Contractor's working drawings shall show details of falsework, rigging, and all other temporary structures, and sizes, capacities, and other characteristics of all machinery and plant employed.

Working drawings shall be submitted to the Engineers in duplicate; one set will be returned to the Contractor approved, or showing the changes or corrections required; duplicate copies shall be resubmitted after correction, until they receive the Engineers' approval. Working drawings shall be corrected or revised whenever and however the Engineers direct, but no approved working drawings shall be altered and

the Engineers' drawings shall not be deviated from without the written consent of the Engineers.

The Contractor shall carefully check all drawings, the Engineers' as well as his own, and if any errors be found they shall be reported to the Engineers, who will make or approve the necessary corrections. The Contractor having undertaken to construct a structure complete and adequate for the purpose intended, and having checked all plans, shall be responsible for the correctness of all drawings; and it is expressly understood that the Engineers' approval of the drawings does not in any measure relieve the Contractor of full responsibility for errors.

Payment for working drawings shall be included in the prices for materials named in the contract. For minor revisions of completed and approved working drawings no extra payment will be made; for material revisions for which, in the Engineers' opinion the Contractor is fairly entitled to extra compensation, the Engineers will fix the amount that the Purchaser shall pay and the Contractor accept as full payment for such revisions.

The Contractor shall furnish without additional charge two complete sets of cloth and as many sets of paper blueprint copies of the working drawings as the Purchaser and the Engineers may desire.

P. 29. *Alteration of Plans*

The Engineers shall have the power to vary, extend, increase, or diminish the quantity of the work, or to dispense with a portion thereof during its progress without impairing the contract; and no allowance will be made the Contractor except for the work actually done. In case any change should involve the execution of work of a class not herein provided for, the Contractor shall perform the same as provided for in the clause entitled "Unclassified Work." In such cases the Engineers will first give a written order, and the Contractor must furnish them with satisfactory vouchers for all labor and materials expended on the work.

P. 30. *Changes*

All clauses of the specifications and contract shall apply to any changes, additions, or deviations, in like manner and to the same extent as to the works at present projected; and no changes, additions, or deviations shall annul or invalidate either the contract or the bond.

P. 31. *Workmanship and Materials*

It is the intent of these specifications to provide for first-class materials and workmanship of every kind in all parts of the structure, and both shall be subject to the inspection and approval of the Engineers at any time during the progress and until the final completion of the work. The

[illegible] work [illegible] constructed in a substantial and [illegible] ner in strict accordance with these specifications, the accompanying plans and such instructions as may be given from time to time by the Engineers, and to the satisfaction and acceptance of the Engineers. The Contractor shall employ suitable mechanics for every kind of mechanical work, and shall, at the request of the Engineers, discharge from the work any foreman or workman whom the Engineers shall deem incompetent, negligent, or untrustworthy.

P. 32. *Inspection in General*

All materials and all processes of manufacture or construction are to be subject to the inspection of the Engineers at all times; and the Engineers or their inspectors shall have free access to all parts of any factories or plants in which any materials are being manufactured or prepared, and to all parts of the work of construction and erection. All facilities for the desired inspection of materials or workmanship shall be furnished by the Contractor as requested. The Engineers or their representatives will pass on all materials of every kind before their use in the structure, and any rejected material must be removed at once from the site or the vicinity of the process of work, or from the right-of-way. The operations of manufacture, construction, and erection will likewise be inspected; and all workmanship or processes deemed to be faulty must be corrected immediately on request.

P. 33. *Inspection of Metal*

All metal will be inspected at the mills and shops. The inspection [illegible] tests of all metal will be made promptly on its being rolled or cast, [illegible] the quality will be determined before it leaves the rolling mill or [illegible]ry.

Material which, subsequent to the tests at the mills and foundries, [illegible] to its acceptance there, develops weak spots, brittleness, cracks, or [illegible] imperfections, or is found to have any injurious defects whatsoever [illegible] be rejected at the shops and shall be replaced by the Manufacturer [illegible] own cost. The inspection of workmanship will be made as the [illegible] of the material progresses, and at as early a period as the [illegible] the work will permit. The Contractor must furnish all facili[illegible] inspecting the workmanship and testing the quality of all ma[illegible] furnished on the order at the mill or shop where the said material [illegible]factured; and the Engineers and their Inspectors shall have free [illegible] to all parts of the plants in which any portion of the material is [illegible]. All tests are to be made by the Contractor for the Inspector [illegible]

[illegible] shall be rolled or work done before the Engineers and the [illegible] notified where the orders have been placed or before [illegible] been made for the inspection. Complete copies of

mill orders and plans must be furnished to the Inspector, and he must be notified in time to be on hand when work is begun on his order. Any delay on the part of the Inspector shall be reported to the Engineers, but no material will be accepted which has not been passed upon by the authorized representative of the Engineers.

P. 34. *Inspection of Other Materials than Metal*

All other materials, processes, and workmanship than metal and machinery and their manufacture shall be inspected at the bridge site, unless the Contractor should elect to have any materials, processes, or workmanship inspected elsewhere, in which case such inspection shall be performed by the Engineers at the places designated by the Contractor; but all expenses incurred in making such inspection shall be borne by the Contractor, and shall be paid promptly from time to time upon presentation of bills for same.

The Engineers shall have the right to take such samples of all materials as they consider necessary for testing or examination.

P. 35. *Final Inspection*

Before the completed work is accepted and paid for, the contractor shall notify the Engineers in writing that it is ready for final inspection. Upon receipt of the notification, the Engineers will arrange to give the entire work a minute and thorough inspection, either in person or through a competent representative who has not been employed regularly on the special work. Any defects or omissions noted during this inspection must be made good by the Contractor without extra charge before the said work will be accepted or paid for in full.

P. 36. *Strictness of Inspection*

All materials and workmanship will be thoroughly and carefully inspected, and the Contractor will be held at all times to the spirit of the specifications; but nothing will be done by the Engineers or Inspectors to give the Contractor needless worry or annoyance, the intent of both specifications and inspection being simply to obtain work that will be first class in every particular and a credit to every one connected with its designing and construction.

P. 37. *Defective Work*

The Contractor, upon being so directed by the Engineers, shall remove, reconstruct, or make good, without charge, any work which the said Engineers may consider to be defectively executed. The fact that any defective material in the structure had been previously accepted by the

oversight of the Inspectors shall not be considered a valid reason for the Contractor's refusing to remove it or to make it good. And until such defective work is removed and made good, the Purchaser shall deduct from the partial payments or the final payment, as the case may be, whatever sum for defective work as may, in the opinion of the Engineers, be just and equitable.

P. 38. *Differences of Opinion*

If any differences arise between the Inspector and the Contractor regarding the meaning of these specifications and the accompanying plans, the Contractor shall bring the same immediately to the attention of the Engineers, who will adjust the said differences.

P. 39. *Position, Gradient, and Alignment*

The entire bridge must be constructed in the exact position required, the finished surfaces of tracks and floors must conform exactly to the elevations and gradient specified, and all parts of both substructure and superstructure must be in exact alignment and properly adjusted. The Contractor must provide all frames, forms, falsework, shoring, guides, and anchors that may be required to insure this result.

P. 40. *Other Contractors' Work*

Each contractor will be required to perform his work in the proper sequence in relation to other work, as may be directed by the Engineers, and properly to join his work to either existing or new construction.

P. 41. *Directions to Contractor*

All of the work is to be under the supervision of the Engineers, and they will give the Contractor directions and instructions from time to time; and all such directions are to be conformed to by the Contractor and by all of his employees and agents. In case that the Contractor shall not be present upon the work at any time when it may be necessary for the Engineers to give instructions, the foreman in charge shall receive and obey any orders that the Engineers may give. On the request of the Contractor or his representative any verbal order given by the Engineers or their representatives will be repeated in writing. Subcontractors or agents of any kind of the Contractor are deemed employees of the Contractor, and they must conform to the directions and supervision of the Engineers in the same way as all other employees are required to conform.

P. 42. *Responsibility for Accidents*

The Contractor shall assume and be responsible for all accidents to men, animals, plant, and materials, due either directly or indirectly to

his operations, before the acceptance of the structure. The Contractor shall place sufficient and proper guards for the prevention of accidents, and shall put up and maintain at night suitable and sufficient lights.

P. 43. *Contractor's Risk*

The Contractor shall bear all loss or damage, from whatever cause arising, which may occur to the works or any portion of them, until the same are fully and finally completed and delivered to and accepted by the Purchaser; and if any such loss or damage occur before such final completion, delivery, and acceptance, the Contractor shall immediately, at his own expense, repair, restore, and re-execute the work so damaged, so that the whole work may be completed properly within the time limit.

P. 44. *Damages*

The Contractor shall indemnify and save harmless the Purchaser against all claims and demands of all parties whatsoever for damages or for compensation for injuries arising from any obstructions erected by the Contractor or his employees, or from any neglect or omission to provide proper lights and signals during the construction of the work.

P. 45. *Loading Metalwork on Cars and Shipping*

Projecting parts, liable to be bent or injured in transit, must be blocked with wood before shipment in such a way as to protect them from injury in handling or in transit. All small parts, such as rivets, bolts, nuts, washers, pins, fillers, and small connection plates, shall be boxed strongly; and the contents shall be marked plainly on each box, in addition to the shipping address. Small plates may be shipped in bundles, securely wired and properly tagged.

In shipping long plate-girders great care is to be taken to distribute the weight properly over the two cars that support them, and to provide means for permitting the cars to pass around curves without disturbing the loading.

In both the handling and shipment of metalwork every care is to be taken to avoid bending or overstressing the pieces or damaging the paint. All pieces bent or otherwise injured will be rejected.

P. 46. *Loading Metalwork on Vessel and Preparing Same Therefor*

Every piece, bundle, or package shall be carefully and plainly marked with the shipping address and destination, with the names and numbers of pieces, and with any other such marks of identification as may be necessary to ensure the correct disposition of the material. All small parts, such as rivets, bolts, nuts, washers, pins, fillers, and small connection plates, shall be boxed strongly, and the contents shall be marked

[illegible] addition to the shipping [illegible] bolted together in pairs; and as many of such [illegible] shall be bundled together with clamps or wire as will be convenient for handling without injury in loading and unloading.

All pieces with open ends, such as truss members with forked ends, or laterals with unsupported plates or angles, or any other parts liable to injury in handling, shall have the ends packed with heavy blocks of timber, bolted thoroughly between the projections or to the body of the member in such a manner as to prevent any bending or other injury in handling or on shipboard. All portals or bracing frames shall be bolted together in pairs, or reinforced by timbers in such a manner as to prevent possibility of injury in transportation.

All nuts on any rods or bolts shipped loose shall be screwed tightly in place, and the threads thereof shall be wound closely with twine so that the nuts cannot become loose and be lost off in handling, and so that the threads shall not be injured.

Especial care must be taken to have every part, piece, and package of each structure loaded in the same vessel. The parts of the different structures must be boxed separately and marked so that there can be no possibility of getting them confused or interchanged. As the omission of any part, however small, would cause great trouble and delay in the field, it is absolutely necessary to avoid any omissions.

The shipping invoices or lists are to be made to correspond to the bundles, boxes, and packages, so that each item on the list can be identified [illegible]ly.

During both the loading on steamer and the unloading from same, special care shall be taken to avoid injuring any of the metalwork; and [illegible] loading shall be so done as not to overstress any part and so as to [illegible] any shifting during the voyage. If, in spite of all precautions, [illegible] of the metalwork be injured, the entire expense to which the [illegible] is put because of such injury shall be borne by the [illegible].

[illegible] the expense involved by these special shipping and loading directions shall be borne by the Contractor, as no extra payment will be allowed [illegible]

P. 47. *Demurrage and Cartage*

[illegible] Contractor for the erection of the superstructure shall unload all [illegible] materials promptly upon their arrival and transport them [illegible] site; and he shall be responsible for and shall pay any and [illegible] or other charges incurred by failure to unload cars or boats [illegible] alotted therefor by the transportation companies. He [illegible] against the shipping lists all parts and pieces of material [illegible] unloaded and shall properly report the same to the [illegible]

P. 48. *Loss of Met*

If any metal or other material be lost
erection or at any time before the compl
work, it shall be replaced at his own ex
responsible for the materials when they are

P. 49. *Contractor's*

As soon as possible after the contract for
the Contractor, if so requested, is to prepare
for their approval a complete list of field plant,
which parts the Contractor already possesses
purchase. If the Engineers are not convinced
plant is sufficient to complete the entire work
time limit set in the specifications, the Contract
list as they may direct.

P. 50. *Notice of Commencement of*

For each bridge covered in the contract the
the Purchaser formal written notice of his desire to
and these shall not be started until proper writ
granted in answer to such notice.

P. 51. *Instrumental Work in*

The Contractor will be given bench-marks and
vals throughout the structure; and he must provi
instruments for determining alignment, elevations,
constructions between such points, subject to the
of the Engineers. In view of this understanding no
be considered because of alleged failure on the part
give the Contractor any information that could be
mental work. Again, while the Engineers make the
ties of finished or partially finished constructions, the
even check the Contractor's bills of materials. Wh
so request, the Contractor shall provide them, at h
intelligent workmen to aid in minor capacity in
for instance, in taping, rodding, picketing, setting
targets, and such like work.

P. 52. *Engineers' Field Off*

The Contractor shall provide at his own expen
some place convenient to the work at the bridge,

sufficiently commodious office, to be used solely by the Engineers during the entire construction of the **said** structure. The location of the said office **in each case** is to be determined by the Engineers; and the character of the building provided must meet with their approval, it being understood that serviceable, but not elaborate nor expensive, construction will be demanded. The said office building shall remain the property of the Contractor after the completion of the structure.

P. 53. *Arch Centres, Forms, Staging, Runways, and Falsework*

The Contractor shall furnish all **arch centres,** forms, staging, runways, and falsework; and there shall be no direct payment therefor, unless there be made properly in writing a special agreement to the contrary. The Contractor shall build all falsework and staging of adequate strength to support safely the loads imposed upon them without injurious deformation or settlement.

The Contractor shall provide suitable forms, and their design shall be adapted to the structure and to the kind of surface required on the concrete. The forms for concrete surfaces which will be exposed to view shall be made of lumber which is dressed on both edges* and on the faces next to the concrete, and the pieces shall be straight so as to insure a tight form that will prevent the leakage of mortar. Forms shall be substantially built and supported in such a manner as to prevent bulging or deformation from the weight or ramming of the concrete. All exposed corners and edges of concrete construction are to be rounded off to a two-inch radius, or as shown on the drawings.

Before the removal of forms the concrete shall have attained a strength which, in the opinion of the Engineers, will prevent injury from such removal. Falsework shall be maintained under all constructions until such time as the concrete is able to sustain both itself and any load that is likely to come upon it with absolute safety to the concrete.

Although the designs for all forms, staging, falsework, and arch centres are to be prepared by the Contractor, they are to be submitted to the Engineers for their approval before being used.

In all cases the Contractor is to be responsible for and must make good any injury arising from inadequate forms or falsework, or from the premature removal thereof.

I. 54. *Removal of Débris*

Upon the completion of his contract **the (or each)** Contractor shall remove all surplus material, temporary structures, and débris resulting from his operations **in new construction, reconstruction, or removal of old**

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* For the very best results the use of tongued-and-grooved lumber or ship-lap is advisable.

inspection and acceptance of
must be secured in writing by the
the equipment from the site.

P. 55. M

Unless otherwise specified all metal
and bolts shall be made of soft steel;
steel; pinions and other forgings of
forgings; bushings of bronze, unless other
timber bearings of malleable iron; and
unless otherwise specified. For special
alloy may be used. Cast iron shall not be
for thick base plates and lamp-posts, or unless
or instructions to do so be given by the Engineer

P. 56. *Requirements for C*

All steel shall be manufactured by the
conform to the following requirements:

The phosphorus and sulphur must not exceed
in the following table:

Impurity	Soft Steel	Medium Steel	Machinery Steel
Phosphorus—Basic steel...	0.04	0.04	0.04
Phosphorus—Acid steel...	0.04	0.06	0.06
Sulphur................	0.04	0.05	0.05

These values are for analyses on test ingots take
of the melts as well as for check analyses on the
case of machinery steel and forged steel. For check
finished material an increase in these values of
will be allowed.

The ultimate tensile strength per square inch
following limits:

Rivet steel........................ 46,000
Medium steel...................... 60,000
Machinery steel.................. 70,000
Cast steel......................... Not
Forged steel...................... Not

The elastic limit, as determined by the drop of the beam, shall be not less than fifty (50) per cent of the ultimate tensile strength.

For rivet steel and medium steel the percentage of elongation in eight inches, as determined on the test specimens, shall be not less than 1,500,000 divided by the ultimate tensile strength, except that for material less than five-sixteenths ($^5/_{16}$) inch and more than three-quarters ($^3/_4$) of an inch in thickness the following modifications will be allowed:

a. For each one-sixteenth ($^1/_{16}$) inch in thickness below five-sixteenths ($^5/_{16}$) inch a deduction of two and one-half ($2\frac{1}{2}$) will be allowed from the specified percentage.

b. For each one-eighth ($^1/_8$) inch in thickness above three-quarters ($^3/_4$) of an inch a deduction of unity will be allowed from the specified percentage.

c. For pins and rollers over three (3) inches in diameter a deduction of five (5) will be allowed from the specified percentage.

For machinery steel and cast steel the elongation in two (2) inches shall be not less than eighteen (18) per cent, and for forged steel not less than twenty-two (22) per cent, as determined on the test specimens.

The reduction of area for cast steel shall not be less than twenty-five (25) per cent, for forged steel not less than thirty-three (33) per cent, and for machinery steel not less than thirty-five (35) per cent, as determined on the test specimens.

In the case of small or unimportant castings, a test to destruction on three castings from a lot may be substituted for the tension and bending tests. This test shall show the material to be ductile, free from injurious defects, and suitable for the purpose intended. A lot shall consist of all castings from one melt in the same annealing charge.

V. 57. *Requirements for Nickel Steel*

The requirements for nickel steel have not reached the same stage of perfection as have those for carbon steel. The American Society for Testing Materials has adopted a very good set of specifications for nickel steel, but the author is assured that a better quality than therein prescribed can be obtained from the Manufacturers. Elastic limits of 55,000 and, possibly, 60,000 pounds per square inch for structural shapes can be secured. This will cost slightly more per pound for the rolled material, but less *in toto* for the finished structure. However, it has been necessary, so far, to take up each case with the Manufacturers as it arises and arrange for the qualities of the steel at such a time. This procedure will be necessary until nickel steel is more generally used and until the better grades are easily procurable.

P. 58. *Identification of Metal*

Each ingot shall be stamped or marked plainly with its proper melt number; and this melt number must be stamped or painted plainly on

blooms, billets, or slabs made from
material throughout its various processes
number must be stamped plainly on
Rivet and lacing steel and small pieces for
be shipped in bundles, securely wired together
number on a metal tag attached thereto.

P. 59. *Methods of Testing*

The chemical determinations of the percentages
sulphur, and manganese shall be made by the
ingot taken at the time of the pouring of each
copy of such analysis shall be furnished to the
shall be made from finished material representing

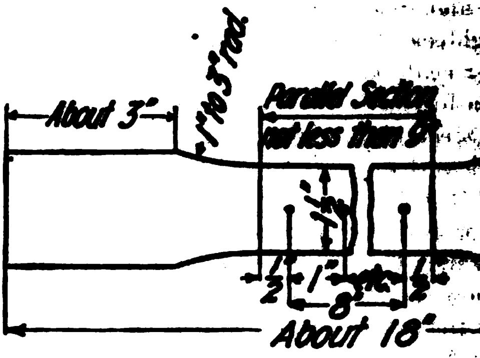

Fig. 79a. Tensile Test Specimen.

by the Engineers. For rollers, pins, and shafts, the
analysis shall be taken at any point midway between
surface of the roller, pin, or shaft, or from a full-sized
or turnings may be taken from a test specimen.
ings shall be taken not less than one-quarter (¼)
of the casting.

The tensile strength, elastic limit, elongation,
plates, shapes, and bars shall be determined by
ture a specimen machined to the form and dimensions
in which the thickness of the test specimen shall
material, except that for plates and eye-bar flats
(1½) inches in thickness the specimen may be
diameter of at least three-quarters (¾) of an inch
nine (9) inches. For pins, rollers, and bars (except
and one-half (1½) inches in thickness, and for
shafts and pins of machinery steel, the test

form and dimensions shown in Fig. 79*b*. Test specimens of rivet steel shall be of the full section of rods as rolled.

Specimens for bending tests shall be similar in outline to those used in tension tests for plates, shapes, bars, and rivets, except that test specimens for eye-bar flats shall always have a thickness equal to the thickness of the finished bar. Bending-test specimens for pins, rollers, and bars (except for eye-bar flats), and for forgings, castings, and shafts and pins of machinery steel, shall be one (1) inch by one-half (½) inch in section.

Test specimens shall be taken from rolled steel in the condition in which it comes from the rolls, except as noted above for plates and eye-bar flats over one and one-half (1½) inches thick, and for pins and rollers, in which cases the axis of the specimen shall be located at any point midway between the centre and the surface and shall be parallel to the axis of the bar. The test specimen shall be taken from the bar itself or from a full-sized extension of the bar. For pins and shafts of machinery steel and for forgings the specimen shall be taken from the piece itself or from a full-sized prolongation of the same parallel to its axis. It shall be taken midway between the centre and surface and shall be cut parallel to the axis of the piece. For cast steel the test specimens shall be cut from coupons moulded and cast on some portion of one or more castings from each melt or from sink heads, if the heads are of sufficient size. If the castings weigh less than five hundred (500) pounds, or are of such design that coupons cannot be attached, two test bars shall be cast to represent each melt; or the quality of the castings shall be determined by tests to destruction as hereinbefore specified.

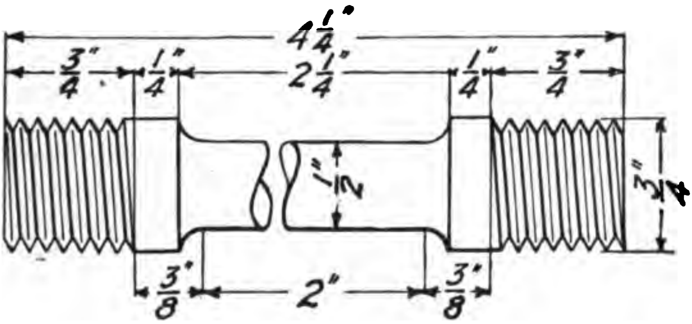

Fig. 79*b*. Tensile Test Specimen.

Every melt from which material is furnished must be represented by the tests, and the test specimens shall be cut by the mill from finished material so selected by the Inspector that the different sizes and shapes in the order shall be as well represented as possible. Material which is to be used without annealing or further treatment shall be tested in the condition in which it comes from the rolls. When material is to be annealed or otherwise treated for use, the test specimens representing such

[illegible]

[illegible] two tensile tests and
specimens from different ingots of each
melts for which the number may be reduced
be made with each tensile test, if required
made on the broken test pieces of the

If material for various shapes is to be
specimens for testing are to be so selected
shapes rolled from such melt. Lots for
(30) tons in weight; and plates rolled in
shall constitute a separate lot, as shall also
nels, or beams. Each melt, however, must be
lot and tested accordingly.

The number of tests of steel castings will de
and importance of the said castings, but each
each melt must be represented by a test.

For forgings at least one test specimen shall
forgings of each kind; but not less than two
for any single kind of forging. Each annealing
melt, must be represented by a test.

If any test specimen shows defective machi
it may be discarded and another specimen substitu

If the percentage of elongation of any tensile
than that specified and if any part of the fracture
quarters (¾) of an inch from the centre of the
specimen or is outside of the middle third of the
8-inch specimen, a retest will be allowed.

The Inspector will be permitted considerable
number of tests required, reducing it when the
increasing it when it does not.

P. 61. *Bending Tests for Steel.*

Specimens of medium steel cut from plates,
bend cold through 180 degrees without cracking
bent portion, as follows: For material three-quarte
under in thickness, flat on itself; for material over
an inch to and including one and one-quarter (1¼)
around a pin the diameter of which is equal to the
men; and for material over one and one-quarter
around a pin the diameter of which is equal to tw
test specimen.

Angles three-quarters (¾) of an inch and less in thickness shall open flat, and angles one-half (½) inch and less in thickness shall bend shut, cold, under blows of a hammer, without sign of a fracture. This test shall be made only when required by the Inspector.

Specimens for eye-bar flats shall bend cold through 180 degrees without cracking on the outside of the bent portion as follows: For material three-quarters (¾) of an inch or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen; for material over three-quarters (¾) of an inch to and including one and one-quarter (1¼) inches in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen; and for material over one and one-quarter (1¼) inches in thickness, around a pin the diameter of which is equal to three times the thickness of the specimen.

Test specimens of pins, rollers, and other bars of medium steel shall bend cold through 180 degrees around a one-inch pin without cracking on the outside of the bent portion.

Test specimens of rivet steel shall bend cold through 180 degrees flat on themselves without cracking on the outside of the bent portion, and nickel steel specimens, bent 180 degrees around a pin the diameter of which is the same as that of the specimen, shall not break with an abrupt, square fracture, but shall show a gradual break and a fine, silky, homogeneous fracture.

Test specimens of machinery steel and forged steel shall bend cold through 180 degrees around a one-inch pin without cracking on the outside of the bent portion.

Test specimens for cast steel shall bend cold through 90 degrees around a one-inch pin without cracking on the outside of the bent portion.

P. 62. *Drifting Tests for Steel*

Medium steel shall be so ductile that the drifting of rivet holes, punched within two (2) inches of a sheared edge, till their diameters are increased fifty (50) per cent, shall not crack the metal. Machinery steel shall not crack, when similarly tested, till the rivet hole is increased twenty-five (25) per cent in diameter.

P. 63. *Fracture of Steel*

All carbon steel broken test pieces of rolled material and all broken eye-bars must show a silky fracture of uniform color. Cast steel may show a fine granular fracture.

P. 64. *Tests of Full-Sized Eye-Bars*

Full-sized eye-bars may be tested to destruction, provided notice be given in advance of the number and size required for this purpose, so

that the material may be rolled at the same time as that required for the structure. The number of tests of full-sized eye-bars will depend upon the size of the order and upon the regularity of the results of the tests. In general, for small orders, the number of tests shall be about three (3) per cent of the number of eye-bars in the order, but never less than two (2) bars for an order for a single span. For large orders the number of tests shall be about two (2) per cent of the number of eye-bars in the order. Should the Inspector find the bars to be very uniform in strength, elasticity, and ductility, and fully up to the specifications, he shall be at liberty to reduce the number of tests of full-sized bars. In the case of testing long bars, it will be allowable to choose a bar at random from a number of finished bars, cut it in two, and upset the end of each piece, thus making two test-bars.

Full-sized bars of medium carbon steel must show an ultimate tensile strength of at least fifty-six thousand (56,000) pounds per square inch. The elongation shall not be less than fourteen (14) per cent in a gauged length of ten (10) feet; and the elastic limit shall not be less than fifty (50) per cent of the ultimate strength of the bar. Any lot of steel bars which meets the preceding requirements shall be accepted, if none of the bars which break in the eye show an ultimate strength, elastic limit, or elongation less than that specified for the body of the bar, unless one-fourth (¼) of the full-sized samples so tested break in the eye. In case of failure to meet any of these requirements, the lot from which the sample bars were taken shall be rejected. All full-sized sample bars which break at less than the ultimate strength specified, or which do not otherwise fill the specifications, shall be at the expense of the Contractor; unless, in case of those that break in the eye, he shall have made objection in writing to the form or dimensions of the heads before manufacturing the eye-bars. All others shall be paid for by the Purchaser at the contract price of finished metalwork on cars at shops, less the scrap value of the broken bars.

P. 65. *Tests of Full-Sized Built Members or Details*

In addition to the specimen tests and eye-bar tests hereinbefore described, the Contractor may be required to make, at his own expense, under the direction of the Engineers or of their Inspector, any tests of full-sized members or details that the Engineers may prescribe, provided that the said members or details are similar to those used on the work, and provided that the total cost to the Contractor of such extra tests does not exceed one-quarter (¼) of one per cent of the total contract price of the work.

P. 66. *Finish of Rolled Steel*

All finished steel as it comes from the rolls shall be free from seams, cracks, and flaws of all kinds, and shall be smooth and clean in finish.

P. 67. *Plates*

Plates rolled on the universal mill may be made from slab ingots, but all other plates shall be formed from slabs made by rolling an ingot and cutting off the scrap. The ingot shall have at least twice the cross-sectional area of the slabs made from it, and the slabs shall be at least six times as thick as the plates made from them.

P. 68. *Forgings*

Forgings shall be free from cracks, flaws, seams, or other injurious imperfections, shall conform to the dimensions shown on the drawings, and shall be made and finished in a workmanlike manner. All forgings shall be annealed. No forging shall be done at less than red heat.

P. 69. *Steel Castings*

Steel castings shall be free from injurious blow-holes, true to pattern, and of workmanlike finish, all corners being properly filleted. All steel castings shall be thoroughly annealed, sufficient time being taken to ensure annealing throughout.

When the bearing surface of any steel casting is finished, there shall be no blow-holes visible exceeding one (1) inch in either dimension, nor exceeding one-half ($\frac{1}{2}$) square inch in area. The length of blow-holes cut by any straight line laid in any direction shall never exceed one inch in any one foot.

The correction of defects in castings by welding electrically, by thermit, or by similar processes will not be permitted.

P. 70. *Iron Castings*

Except where chilled iron is specified, all iron castings shall be of tough gray iron, with not more than 0.10 per cent sulphur. They shall be true to pattern, out of wind, and free from flaws and excessive shrinkage. They shall be substantially of the thicknesses required by the plans, and they shall have sharp and clean angles, lines, and mouldings and filleted corners.

Tests shall be made on a round bar one and one-quarter ($1\frac{1}{4}$) inch in diameter and 15 inches long. The transverse test shall be made on a length of 12 inches with a load at the middle. The minimum breaking load so applied shall be 2,900 pounds, with deflection of at least one-tenth ($\frac{1}{10}$) inch before rupture.

P. 71. *Bronze Bushings*

For low-unit pressures on journal bearings and where the speed is high, all bushings shall be composed of phosphor bronze of the following composition:

Phosphorus

The amount of tin shall not be less
than eleven (11) per cent. The amount
eight (8) per cent nor more than eleven (1
phosphorus shall not be less than seven-tenths
(1) per cent. The amount of ingredients
and phosphorus shall not exceed one-half (½

Specimen tests of the alloy must give the

Compression

Elastic limit in pounds per square inch
Permanent set in inches from a load of 10
pounds per square inch...........

The elastic limit is based on a set of

Tension

Yield point in pounds per square inch....
Ultimate strength in pounds per square inch
Elongation, percentage in two inches......
Reduction of area, per cent...................

For high unit pressures on journal bearings
low, and for centre disks of centre-bearing swing-spans
shall be of the following composition:

Copper...
Tin...
Phosphorus......................................

The amount of tin shall not be less than thirteen
more than fifteen (15) per cent. The amount of
be less than seven-tenths (7/10) per cent nor more than
amount of ingredients other than copper, tin, and
exceed one-half (½) of one per cent.

The approximate physical results from this compo
with an area of one (1) square inch and one (1) inch

Compression

Elastic limit in pounds per square inch.....
Permanent set in inches from a load of 100,0
pounds per square inch..............

The elastic limit is based on a set of 0.001 inch

P. 72. *Babbitt Metal*

Babbitt metal shall have the following composition:

Tin, two (2) parts; zinc, one (1) part; and to this must be added antimony to the amount of five (5) per cent of the total weight of the tin and zinc.

P. 73. *Pins and Shafts*

Pins and shafts up to four (4) inches in diameter, unless otherwise specified, may be rolled; those of greater diameter shall be forged. The rounds from which the pins and shafts are to be turned must be true, straight, and free from all injurious flaws or cracks. All forged pins and shafts shall be reduced to size from a single bloom or ingot until perfect homogeneity is secured throughout the whole mass. The blooms or ingots shall have at least three times the cross-sectional area of the finished pins or shafts made from them. No forging shall be done at less than red heat.

All pins and shafts shall be turned accurately to a gauge, and shall be finished perfectly round, smooth, and straight. All pins up to six (6) inches in diameter shall fit the pin holes within one-fiftieth ($\frac{1}{50}$) of an inch; and all pins over six (6) inches in diameter shall fit their holes within one-thirty-second ($\frac{1}{32}$) of an inch.

The Contractor shall provide a sufficient number of pilot nuts for each size of pin to preserve the threads while the pins are being driven.

P. 74. *Reinforcing Bars*

All bars for reinforcing shall be deformed bars having lugs, corrugations, or other deformations which present to the concrete a positive shoulder having an angle of not less than forty-five (45) degrees with the axis of the bar. Bars with deep corrugations liable to form air-pockets or with deformations having a wedging action tending to split the concrete will not be accepted. All reinforcing material shall be rolled from billets and shall be of medium steel, uniform in character, and manufactured by the open-hearth process. Any attempt to substitute steel manufactured by the Bessemer process, or from old steel rails, will be considered a violation of the contract and adequate reason for its cancellation. All finished material as it comes from the mills shall be free from all flaws, cracks, or other defects, and must have a clean finish.

P. 75. *Permissible Variations in Weight and Gauge*

The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified, except in the case of sheared plates,

which shall be covered by the following
to single plates:

(a) *When Ordered to Weight.*—

For plates 12½ lbs. per sq. ft. or over:
Under 100 in. in width, 2.5 per cent
weight;
100 in. in width or over, 5 per cent
weight.

For plates under 12½ lbs. per sq. ft.:
Under 75 in. in width, 2.5 per cent
weight;
75 to 99 in., inclusive, in width, 5 per cent
below the specified weight;
100 in. in width or over, 10 per cent
the specified weight.

(b) *When Ordered to Gauge.*—The thickness
vary more than 0.01 in. under that

An excess over the nominal weight
dimensions on the order shall be allowed
more than that shown in the following
of rolled steel being assumed to weigh

Thickness Ordered, in.	Nominal Weight, Lbs. per Sq. Ft.	ALLOWABLE EXCESS (EXPRESSED AS			FOR WIDTH OF PLATE AS
		Under 50 in.	50 to 69 in. Incl.	70 in. or Over	Under 75 in.
⅛ to $\frac{5}{32}$	5.10 to 6.37	10	15	20	...
$\frac{5}{32}$ " $\frac{3}{16}$	6.37 " 7.65	8.5	12.5	17	...
$\frac{3}{16}$ " ¼	7.65 " 10.20	7	10	15	...
¼	10.20	...	...	..	10
$\frac{5}{16}$	12.75	...	...	..	8
⅜	15.30	...	...	..	7
$\frac{7}{16}$	17.85	...	...	..	6
½	20.40	...	...	..	5
$\frac{9}{16}$	22.95	...	...	..	4.5
⅝	25.50	...	...	..	4
over ⅝	.....	...	...	..	3.5

P. 76. *Sheared Edges*

All sheared and hot-cut edges shall have not
(¼) inch of metal removed by planing to a
Lacing-bars, fillers, stay-plates, lateral-bracing
and bottom edges of plate-girder webs only will
requirement. No sharp or unfilleted re-entrant
anywhere in the work.

P. 77. *Drifting*

No drifting to distort the metal will be allowed. If a hole must be enlarged to admit a rivet it must be reamed.

P. 78. *Straightening*

All material must be thoroughly straightened before being laid off or worked in any way.

P. 79. *Annealing*

In all cases where a steel piece, in which the full strength is required, has been partially heated or bent, the whole piece must be subsequently annealed. In pieces of secondary importance where the bending is slight, the said bending is to be done cold, and no annealing in such cases will be called for. Crimped web-stiffeners will not need annealing.

P. 80. *Rivet Holes*

Rivet holes must be accurately spaced; the use of drift pins will be allowed only for bringing together the several parts forming a member, and they must not be driven with such force as to distort the metal about the holes. The distance between the edge of any piece and the centre of a rivet hole must never be less than one and a half (1½) inches, excepting for lattice bars, small angles, and where especially shown otherwise on the Engineers' drawings; and wherever practicable this distance shall be at least twice the diameter of the rivet.

P. 81. *Rivets*

Rivets when driven must completely fill the holes, and must have full heads concentric with the rivet holes. Shop rivets must be driven, whenever practicable, by a machine capable of retaining the applied pressure after the upsetting is completed. Elsewhere the pneumatic hammer shall be used if possible. The rivet heads must be full and neatly finished, of approved hemispherical shape, in full contact with the surface, or be counter-sunk when so required, and of a uniform size for the same [illegible] rivets throughout the work; and they must pinch the connected pieces thoroughly together. Flattened heads may be used in certain places, if necessary for clearance. Except where shown otherwise on the drawings, all rivet diameters are to be seven-eighths (⅞) of an inch. [illegible] or imperfect rivets will be allowed to remain in any part of the [illegible]

[illegible] rivets have a grip exceeding four (4) inches they are to be tapered, [illegible] of total taper varying from one-sixteenth ($\frac{1}{16}$) to three-six[illegible] of an inch according to the length of grip. All long rivets are [illegible] points cooled slightly by dipping them in water.

P. 82. *Fiel*

All field rivets are to be [illegible] are to be approved by the Engineers. [illegible] of uniform circular section throughout (except long rivets, which must be tapered and [illegible] must be free from projections or other imperfections the head from fitting closely before the rivet is [illegible]

The Manufacturer of the Metalwork* is to [illegible] ment of field rivets, with an excess allowance [illegible] rivet used equal to fifteen (15) per cent of the [illegible] for plus ten (10); and the Erecting Contractor† will [illegible] at his own expense any rivets above that

P. 83. *Sub-Punching and*

All rivet holes in steel work, if punched, three-sixteenths (3/16) of an inch in diameter rivet intended to be used, and they shall be sixteenth (1/16) inch greater than that of the said

All the pieces to be riveted together shall be together before the reaming is done; for the punching and reaming are to insure the correct the avoidance of holes of excessive diameter, as well if not all, of the incipient cracks started by the is to be done by means of twist-drills, the use of prohibited except where twist-reamers cannot be must be at right angles to surface of member, and edges of holes under heads must be slightly rounded are driven. All holes for field rivets, excepting sway-bracing, when not drilled to an iron templet, shall the connecting parts are temporarily assembled.

Punching shall not be permitted in any piece in of the metal exceeds the diameter of the cold rivet but all such pieces shall be drilled.

Holes in lattice bars and batten plates may be

All punched work shall be so accurately done component pieces are assembled and before the forty (40) per cent of the holes can be entered easily eter one-sixteenth (1/16) of an inch less than that

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* Replace by *Contractor* if the Manufacturer erects.

† Replace by *he* if the Manufacturer erects.

eighty (80) per cent by a rod of a diameter one-eighth ($\frac{1}{8}$) of an inch less than same; and one hundred (100) per cent by a rod of a diameter one-quarter ($\frac{1}{4}$) of an inch less than same. Any shopwork not coming up to this requirement will be subject to rejection by the Inspector.

Graphite shall, preferably, be the lubricant for reaming; but oil may be used, if desired. The Contractor will not be allowed to employ soap-suds without special permission from the Engineer.

P. 84. *Reaming Connections*

Wherever practicable, reaming must be done after all the pieces which are to be fastened together by the same rivets have been assembled. If necessary to take the pieces apart for shipping or handling, the respective pieces reamed together must be so marked that they may be reassembled in the final setting up. No interchanging of pieces after reaming will be allowed.

All riveted trusses and all towers for movable bridges shall be assembled and drilled or reamed in the shop.

All spliced members shall be put together in the shop, and the field rivet holes therefor shall be reamed to a fit while these members with their splice plates are in place. All spliced chord sections or columns must be assembled and strung out in the shop in lengths of not less than three sections, and after being drawn into contact at the joints and lined up perfectly with splice plates in place, the field rivet holes shall be reamed to a fit before taking apart, and the assembled parts with their splice plates shall be match-marked so that they may be reassembled in the final setting up.

All field connections in the floor system must be reamed to a fit either while the members are assembled in the shop, or by using an accurate steel or cast iron templet not less than one inch thick.

P. 85. *Marking and Match-Marking*

All members shall be plainly and well marked in accordance with the erection diagram, and all members assembled for reaming or drilling shall be match-marked so that they may be readily assorted and reassembled in the field.

P. 86. *Milling Beams and Stringers*

[illegible] floor-beams must be milled on both ends to correct length after [illegible] connection angles are in place, and the said end connection angles [illegible] accurately fitted that not more than one-sixteenth ($\frac{1}{16}$) of an [illegible] taken off them at their roots. The abutting ends of canti-[illegible] must be milled in the same manner.

[illegible] connection angles of stringers are to be riveted to the webs

[illegible]

with the whole stringer [illegible]

[illegible] correct length of stringer and the [illegible]

P. 87. *Built Members* [illegible]

Built members must, when finished, be true [illegible] buckles, or open joints between the component [illegible] faces of compression members must be planed [illegible] so that they shall be in as perfect contact [illegible] by such means; and all such finished surfaces [illegible] lead and tallow before shipment from the shop. [illegible]

The ends of all webs and of chord or flange [illegible] other webs must be faced true and square [illegible] end stiffeners must be placed perfectly flush [illegible] as to afford a proper bearing. Filling plates [illegible] must be practically flush with the said angles, and [illegible] ject outside of same at the bearings. All [illegible] driving fit at both upper and lower flanges of [illegible] be allowed to project beyond the flange angles [illegible] one-eighth (⅛) of an inch from faces of same.

All filling and splice plates in riveted work [illegible] the flanges sufficiently close to be sealed by the [illegible] sion of water; but they need not be tool finished [illegible] dicated either on the drawings or in the [illegible] web plates must be faced so as to provide [illegible] entire depth, unless special written permission to [illegible]

P. 88. *Limits of Error in* [illegible]

No piece having an error of one-thirty-second [illegible] tween centres of pin-holes, or one-fiftieth ($^1/_{50}$) of [illegible] eter of the pin or its hole, will be accepted.

P. 89. *Camber*

Truss spans shall be cambered as noted on the [illegible] spans need not be cambered.

P. 90. *Correction of Secondary* [illegible]

The secondary stresses in riveted trusses are to [illegible] ening and shortening the various truss members [illegible] respective shortening and lengthening under dead [illegible] live-plus-impact load, drilling or reaming the chord [illegible] are assembled in straight lines, then forcing the [illegible] proper positions for connection to each other [illegible] the holes in the joints.

P. 91. *Eye-Bars*

Except in the case of loop-eyes, no weld will be allowed in the body of the eye-bar. The heads of the eye-bars shall be made by upsetting, rolling, or forging into shape. A variation from the specified dimensions of the heads will be allowed, in thickness of one-thirty-second (1/32) of an inch below and one-sixteenth (1/16) of an inch above that specified, and in diameter of one-fourth (1/4) of an inch in either direction. Eye-bars must be perfectly straight before boring.

P. 92. *Pin-Holes*

All pin-holes must be bored truly parallel and at right angles to the axis of the member, unless otherwise shown on the drawings; and in pieces not adjustable for length, no variation of more than one-thirty-second (1/32) of an inch will be allowed in length between centres of pinholes.

P. 93. *Turned Bolts*

When members are connected by bolts which transmit shearing-stresses, the holes must be reamed parallel, and the bolts must be turned to a driving fit. The threaded portions of turned bolts shall be one-eighth (1/8) of an inch less in diameter at root of thread than the body of the bolt.

P. 94. *Turnbuckles, Nuts, Threads, and Washers*

All sleeve-nuts, turnbuckles, and clevises must be made so strong and stiff that they will be able to resist without rupture the ultimate pull of the members which they connect, and without distortion the greatest twisting moment to which they could ever be subjected. They must be made so that the threaded lengths of the rods engaged can be verified.

The dimensions of all square and hexagonal nuts, except those on the ends of pins, shall be such as to develop the full strength of the body of the adjustable member. No round-headed bolts will be allowed unless specially indicated on the drawings.

Washers must be used under the heads of all timber bolts when the bearing is on the wood, and all washers and nuts must have uniform [illegible]. All washers are to be made of malleable iron of good quality, [illegible] must be sufficiently large and thick to provide properly for [illegible] the pressure due to the greatest allowable tension in the bolt [illegible] area of the washer. They must be finished in a neat and work-[illegible] and must be free from all defects.

[illegible], except those on the ends of pins, must be of the United [illegible]. Each adjustable nut must be provided with an effective [illegible]-washer.

segmental rollers and the rolling
ately turned to a gauge, and must b
of the correct diameter or diameters,
segmental rollers need not be finished, but
and true. The tongues and grooves in plates
so as to prevent lateral motion. Roller-be

P. 96. *Anchor Bolts*

All bed plates and bearings must be bolted
fox bolts or by bolts set in the masonry during
case of fox-bolting, the Contractor for Erection
set the bolts to place with Portland cement
shall be of soft steel with United States standard
of the nuts for all anchor bolts shall be equal to or
eter of the bolt. Anchor bolts are not to be pa
but the exposed portions thereof, after erection, shall
of paint when the other metalwork is painted.

P. 97. *Steel Hand-Rails*

Hand-rails,* **as shown on the accompanying dra**
nished by the Manufacturer of the Metalwork and
Contractor for Erection. They are to be laid and
line and elevation from end to end of structure.
vided are to be made perfectly operative. The
be finished to the satisfaction of the Engineers.

P. 98. *Name-Plates, Patent-Plates, and*

Name-plates, patent-plates, and year-plates of
by the Engineers shall be furnished and attached
and in the manner required by the Engineers. Th
iron or bronze, as specified on the drawings.

I. 99. *Steel Tapes*

The Contractor who furnishes the metalwork shall
the execution of his contract, furnish the Purchaser,
steel tape fifty (50) feet long, and another ......
long, both guaranteed to agree exactly with the
manufacturer of the metalwork.

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* Omit portion in bold face type if the Manufacturer

100. *Machinery in General*

The first part of the example given will suffice for this clause for movable bridges in general except where such additional requirements are deemed advisable as given for swing spans.

EXAMPLE

Unless otherwise indicated on the drawings, all cast portions of the machinery shall be made of cast steel, all rolled shafts and pins shall be made of machinery steel, and all forgings shall be made of forged steel. The machinery shall be finished and machined according to the best machine shop practice and to the satisfaction of the Engineers; and the limits of accuracy which the Contractor desires to observe in machining the work and the allowances for taper-shrinkage or pressed fits shall be placed on the Contractor's working drawings, but the approval of the said drawings by the Engineers shall not relieve the Contractor from full responsibility for the satisfactory construction and operation of the machinery. All machinery shall be satisfactory to the Engineers, and the Contractor shall furnish the Purchaser with a guarantee (satisfactory to the Purchaser) to replace, free of charge, f. o. b. cars at the railway station nearest the bridge site (to be designated by the Purchaser) any and all parts which may fail or otherwise prove to be defective within one year of the date on which the bridge is put in service.

If it should be found that the Manufacturer has varied from the Engineers' plans without receiving from them special written permission to do so, and if such variation should, within the said one year, cause any break-down or accident, the Contractor not only will be required to repair the damage to the machinery but also will be held pecuniarily responsible to the Purchaser for all expense to the latter due to such failure. If the Contractor have any objection to any features of the machinery, as designed, he must state his objection immediately in writing to the Engineers before any parts are manufactured; otherwise his objections will be ignored, if offered as excuse for defective or broken machinery.

All parts of the machinery in contact with other parts or with its supports shall be machined so as to provide true bearing; and all surfaces in rotating or sliding contact with other surfaces shall be finished true to dimensions and polished. All bearings shall be provided with oiling devices satisfactory to the Engineers. All bronze bushings shall be bored and scraped to a true fit on the journals. Other surfaces [illegible] left in a neat and workmanlike condition, but need not be machined [illegible] the sake of appearance. All bearings shall be attached to their [illegible] turned bolts of the same diameters as the holes, and dowels [illegible] if the Engineers require them.

[illegible] shall be properly cleaned; and all fins, seams, and other

irregularities shall be removed, so
smooth surfaces. Drainage holes of
places where water is likely to collect.
of one-sixteenth ($\frac{1}{16}$) of an inch in bolt holes.
the diameter of the shank at least
diameter of the threaded portion, and they
the bolt holes.

For the swing span all track segments are to be
at the joints. The surfaces on which the rollers
true bevel. Toothed segments forming the rack
and particular care shall be taken to make the
to have the pitch of the teeth accurate at the
the upper face of the teeth shall be planed, and
scribed thereon. The rack segments shall be so
those of the track as to have the centre line of the
with the pitch line of the rack.

All rollers shall be turned to the correct
chamfered. The hubs shall be accurately bored

Pivot-stands and centre castings of swing
ished and fitted. Special care must be taken
truly at right angles to the axis, and turned
centric with the axis.

The rollers, tracks, drum, and girders over drum,
assembled in the shop before shipment, all holes
the sections being match-marked. Every roller
on both the upper and the lower tracks during a
span. Before the assembling of the rollers is done,
on both the upper and the lower track segments a
eter, which circles will come a trifle inside of the
then, after the turn-table is perfectly adjusted, each
where these circles touch it. After the turntable
roller is to be set up properly in a lathe, and the
be chamfered off exactly to the points marked, so
table is set up in the field, if the exterior of each
to the circles on the two tracks, the rollers will all be
tions. These lines on the tracks will serve also
rollers whenever the turntable is to be adjusted.

Steel discs and their bearings must be accurately
to gauge, and must be oil-tempered. After
ately ground to their final finish. Steel and
have their sliding surfaces finished to a high polish.

All journals shall be turned with a fillet at each
called for on the drawings, and they shall have
in their bearings. All hubs of wheels, pulleys,
bored to fit close on the shaft or axle. If the hub

a collar, the end next to the bearing must be faced. Holes in hubs of toothed gear-wheels must be bored concentric with the pitch circle.

All gears shall be made of cast steel and shall have cut teeth. All teeth are to be of the involute type having twenty (20) degrees obliquity. All bearings shall be bushed, as shown in the drawings. All pinions shall be made of forged steel and shall have their teeth cut from the solid metal.

The principal parts of the machinery on the movable span and the portions of the structural steelwork which support it shall be assembled in the shop, and all holes for connection of the machinery to the steelwork shall be drilled while the parts are thus assembled. All bolts for connecting the various parts of the machinery to other parts or to the steelwork shall be turned to a driving fit wherever shear may come upon them.

P. 101. *Hand-Operating Machinery*

In addition to the power machinery there is to be, as shown on the accompanying drawings, machinery that will operate the movable span by man-power in case of any break-down of the other machinery or of any failure of power.

MACHINERY FOR VERTICAL LIFT SPANS

P. 102. *Tower-Sheave Bearing Connections*

Each pair of bearings shall be assembled, aligned, and adjusted to correct relative position with their shafts placed in them, on a steel plate not less than one-quarter (¼) inch thick; and holes shall be drilled through the plate corresponding to the holes for bolts in the bearings. The plate shall then be placed and aligned on the structural supports—which must be completely assembled—and the bolt holes drilled. A separate plate shall be employed for each pair of bearings; and it shall not be shorter than the total length of the shaft nor narrower than the total width of the bearings.

P. 103. *Indicator*

A mechanical indicator for the movable span shall be placed in the operator's house, and so arranged as to give the operator the exact location of the movable span at any time during the operation.

P. 104. *Counterweight and Operating Ropes and Their Attachments*

All wire rope shall be made by John A. Roebling's Sons Company, [illegible] manufacturer approved by the Engineers.

The counterweight ropes shall be made of plow steel wire and [illegible] of six (6) strands of nineteen (19) wires each, laid around a [illegible]

[illegible] shall be laid up in the best possible manner and shall

[illegible]

in the presence of an

for sizes 0.076 inches to

physical properties:

The tensile strength per square inch

pounds for wire 0.190 inch to 0.151 inch

pounds for wire 0.150 inch to 0.126 inch

pounds for wire 0.125 inch to 0.101 inch

pounds for wire 0.100 inch to 0.076 inch

b. The total ultimate elongation, measured shall not be less than 2.4 per cent.

c. The number of times a piece 6 inches its longitudinal axis without rupture shall by the diameter in inches.

d. The number of times the wire can be to the right and to the left over a radius equal out fracture shall be not less than six (6). This mechanical bender so constructed that the wire radius of the jaws and is subjected to as little

E. Each rope shall, if practicable, be made in strength, as determined by the tests described in less than

5,000 lbs. if ¼" diameter	151,000
12,000 lbs. if ⅜" diameter	176,000
21,000 lbs. if ½" diameter	198,000
34,000 lbs. if ⅝" diameter	239,000
47,000 lbs. if ¾" diameter	270,000
63,000 lbs. if ⅞" diameter	299,000
81,000 lbs. if 1" diameter	378,000 lbs.
101,000 lbs. if 1⅛" diameter	474,000 lbs.
124,000 lbs. if 1¼" diameter	

In case the breaking strength of the rope fall above, the entire length from which the test pieces replaced by the Manufacturer with a new length, the ical qualities of which come up to the specifications.

F. All sockets used in connection with this without welds, from solid steel, if it is possible to where this cannot be done, they may be steel castings specific written permission of the Engineers. In sions shall be such that no part under tension shall 65,000 pounds per square inch when the rope is strength as named above. The sockets must be

[illegible] absolutely reliable and which will not permit [illegible] slip in its connection to the socket.

G. In order to demonstrate the strength of the rope and its fastenings, a number of test pieces, not more than 10 per cent of the total number of finished lengths which will be ultimately made, nor less than two from each original long length, and not more than twelve (12) feet long, shall be cut, and shall have sockets, selected at random from those which are to be used in filling the order, attached to their ends. These test pieces are to be stressed to destruction in a suitable testing machine. Under this stress the rope must develop the ultimate strength given in paragraph E. The sockets must be so fastened to the rope that there shall be no slipping of the rope in the basket. If slipping should occur, then the method must be changed until one is found whereby slipping can be entirely avoided. The sockets themselves shall be stronger than the rope with which they are used. If one should break during the test, then two others shall be selected and attached to another piece of rope and the test repeated, and this process shall be continued until the inspector is satisfied of their reliability, in which case the lot shall be accepted. If, however, 10 per cent or more of all the sockets tested break at a load less than the minimum ultimate strength of the rope given in paragraph E, then the entire lot shall be rejected and new ones, made of heavier type or of stronger material, shall be furnished.

The length of each rope from inside of bearing to inside of bearing of sockets shall be determined, and a metal tag having the said length stamped thereon shall be securely attached to the said rope.

The Purchaser reserves the right to test each wire rope connection, after its attachment is made, up to one-half of the ultimate strength of the rope, and if it show the least sign of weakness, it shall be rejected and replaced.

The Manufacturer shall provide proper facilities for testing, and shall make at his own expense all the tests required. All tests shall be made in the presence of an Inspector who represents and is paid by the Engineers.

All ropes shall be shipped on reels the minimum diameter of which is at least thirty times that of the ropes, and they shall be uncoiled for use by revolving the reel.

P. 105. *Rope Dressing*

As soon as the movable span is ready for operation, the Erecting Contractor shall furnish and apply to all ropes two coats of Whitmore's No. 1 rope dressing, manufactured by the American Specialty Manufacturing Company, of Cleveland, Ohio, or of any other dressing which the Engineers approve. The dressing shall be applied to the satisfaction of the [illegible]

I. 106. *Locking Apparatus*

[illegible] on the drawings, there is to be an apparatus for locking the [illegible] into place before it is used for passage. This apparatus is

[illegible]
is to be operated by
to be released before the bridge can
has to be applied before the bridge can be

P. 107. *Equalizing Levers*

The equalising levers connecting the ropes to
be of either forged or rolled medium steel,
more than four (4) inches in diameter shall
smaller than four (4) inches in diameter shall be
steel, in accordance with these specifications.
finished substantially to the dimensions shown

V. 108. *Counterweights*

There should be presented here a complete
weight, or else a reference to the drawings if the
there in detail. The method of determining the
be used shall be given as well as the method of
weight. The exact balancing of the span shall
to be used shall likewise be specified.

Example

The counterweights shall be constructed, as shown
ing drawings, of steel frames surrounded by concrete.
tion of the first counterweight is begun the Contractor
of concrete, not less than ten cubic feet in volume,
used in the counterweights; and these blocks, when
carefully measured and weighed, to determine as near
probable weight of the concrete in the counterweight
work, both subject to the Engineers' approval, shall
ample strength to support themselves and the coun
struction; or else the counterweights shall be built
the counterweight frames, which shall be connected
cables that pass over the main sheaves and attach
Counterweights must be of correct weight to balance
Contractor shall adjust and correct them as required.
faces of concrete of counterweights are to be painted
special concrete paint to be specified by the Engineer

Electrical Equipment

P. 109. *Material and Workmanship*

In the electrical machinery the material and
first class in every particular, and the said machi

in every detail and device necessary for the perfect operation and control of the movable span. The machinery is to be manufactured and erected to the satisfaction of the Purchaser, and the Contractor must furnish the Purchaser a satisfactory guarantee to replace, free of charge, any parts which may fail or otherwise prove defective within a period of twelve (12) months after the work is officially accepted. If the Contractor have any objections to any features of the electrical equipment as designed, he must state his objections immediately in writing to the Engineers; otherwise his objections will be ignored, if offered as excuse for defective or broken apparatus.

I. 110. *Direct-current Electric Motors*

Direct-current electric motors shall be employed to perform the various operations necessary to open and close the movable span. Direct current at......volts nominal pressure shall be used. Motors of the size, character, and make specified on the drawings, or equivalent motors acceptable to the Engineers, shall be erected, installed, and properly connected with the machinery and with the controllers. Each motor shall be capable of producing the maximum starting torques and the normal torques with corresponding speeds, as indicated on the performance curves shown on the drawings. They shall further be subjected to the standard test of the American Institute of Electrical Engineers, viz.: After one-half hour's run at the rated load and voltage under normal conditions of ventilation and cooling, the temperature of any part of the motor windings shall not exceed by more than fifty (50) degrees Centigrade that of the surrounding air, if the said temperature of the surrounding air is twenty-five (25) degrees Centigrade. The permissible rise in temperature shall be increased or decreased one-half of one per cent for each degree Centigrade that the surrounding air is less than or greater than twenty-five (25) degrees Centigrade. Duplicate motors shall operate at substantially the same speed under the same load and voltage. Each motor shall be tested by the Manufacturer before shipment, and shall demonstrate its ability to meet the above requirements for temperature, torque, and speed. They shall be weatherproof, and shall have steel frames, ironclad armatures, and feet extended from frames, all as shown on the drawings.

The Contractor shall furnish, free of charge, the following additional parts for each size of motor, viz.: one armature, one set of field coils, one set of carbon brushes, and one set of back gears, if these are supplied with the motors. All these parts shall be fitted and furnished in such a manner that they may be installed in their places without further fitting or adjustment.

I. 111. *Alternating-current Electric Motors*

Alternating-current electric motors shall be employed to perform the various operations necessary to open and close the movable span. A......

[illegible]
installed, and properly connected
tions. Each motor shall be
Institute of Electrical
at the rated load, voltage, and
of ventilation and cooling, the
windings shall not exceed by more than
that of the surrounding air, if the
twenty-five (25) degrees Centigrade. The
ture shall be increased or decreased one-half of
gree Centigrade that the surrounding air is
twenty-five (25) degrees Centigrade. Duplicate
substantially the same speed under the
motor shall be tested by the Manufacturer
demonstrate its ability to meet the above
and the requirements for torque and speed
They shall be weatherproof, and shall have steel
from the frames, all as shown on the drawings.

The Contractor shall furnish free of charge
parts for each size of motor, viz.: (Give the
of motor used that are subject to destruction
the insulation, etc.).

I. 112. *Controllers and Resista*

*There shall be one .... type controller
(machinery) house, capable of governing the
controller shall be of the .... type with
shall be so arranged and wired that the solenoid
shaft of the motor will be released on the first point
the motor started on the second point of the control
shall be equipped with magnetic blow out, and, if fitted
reversing cylinder, shall be so interlocked that the
thrown when the motor is taking current.

Suitable resistance of ample capacity shall be
motor can be started and operated from standstill
causing injurious sparking at the commutators of the
shock or jar to the bridge. All resistances shall be
free from injurious vibration and so as to have free

(Add similar clauses for additional motors, if
ployed, as for end lifts, locks, etc:)

---

* This clause as written assumes that there is one motor
operating the span. If there be more than one motor or
ably modified.

[illegible] controls shall be so interlocked that [illegible] operation can take place until the preceding operation [illegible] properly performed.

V. 113. *Electric Power Wiring and Electric Cables*

This clause will depend on the type of movable span employed. In the case of a draw-span it is generally necessary to carry the cables from the fixed spans under the river to the pivot pier, although in some instances it is possible to carry the wires overhead to the centre of the span. In lift and bascule spans the supply wires, as a rule, can be carried on the superstructure without passing under the river.

This clause should give the source of supply at which the Contractor has to make his connections. It should specify the size, construction, and characteristics of the wires and cables required, the size and quality of conduits, and the apparatus for protecting the feeders, as well as the layout and workmanship of the complete system.

EXAMPLE

All wiring from a source of supply not more than one hundred (100) feet distant from each end of the movable span, together with all necessary apparatus and appurtenances, shall be furnished and placed by the Contractor.

All wiring on the spans shall be double-braided, rubber-covered, copper wire of ample capacity to carry the currents required by the motors for maximum loads to the switchboard with drop in potential not to exceed five (5) per cent. No wire shall be less than No. 12 B. & S. gauge. The wires shall be drawn, without injury to either themselves or the insulation, into loricated pipe conduits or equivalent conduits acceptable to the Engineers. These conduits shall have as few bends as possible, and shall be directly connected to all apparatus so as to provide a weatherproof housing for the wires. Each feeder shall be protected by a pole switch, [illegible] and lightning arrester mounted on a non-combustible and non-absorbent insulating base. (For alternating currents all the phase wires shall be placed in one conduit.)

FOR THE VERTICAL LIFT SPAN.—Running vertically on the towers there shall be No. 000 trolley wires properly fastened to and insulated from [illegible] as shown on the drawings. These trolley wires shall be connected [illegible] sources of supply by 300,000 cm. double-braided, rubber-covered [illegible] composed of nineteen (19) strands of tinned copper wire of not [illegible] ninety-eight (98) per cent conductivity. Collectors attached to [illegible] wires on the span shall engage the trolleys for the full movement [illegible]

[illegible] DRAW SPAN.—The conductors for the swing span shall consist [illegible] subaqueous cables with two independent conductors,

one for the supply and one for the
of sufficient capacity to carry safely
bridge with full overload on the
be composed of nineteen strands of tinned
ninety-eight per cent conductivity. The
not be less than five thirty-seconds of an inch
than thirty per cent of pure Pará rubber.
tape, and a lead sheath three thirty-seconds
three per cent of tin alloy; also a substantial
and an armor of galvanized steel wire of
of the cable. The cables shall show at sixty
sulating resistance of five hundred megohms
electrification. These cables shall be brought
with collector rings to carry the current to the
the bridge is swinging. These collector rings
metallic casings.

The subaqueous cables shall be carried
fixed span to the pivot pier in a trench to be
not less than five feet deep and filled up after the

Proper return circuits shall be provided to
swing span to the ground circuit.

P. 114. *Switches and Switch*

The switchboard shall be of first-quality slate,
switches, cut-outs, fuses, etc., thereon may be
and operated by the bridge operator. All switches
tons shall have suitable name plates and shall
accordance with their purpose and use. The switch
on a substantial iron support braced to the wall.

An automatic circuit breaker equal in quality
I-T-E Standard and of ample capacity shall be
cuit between the feeders and the switchboard devices
line of motors, and each line of lighting, signal,
shall be protected by suitable fuses of a pattern
neers. Switches of the quick-break, railway type
each feeder, and for each motor circuit, each
circuit, and each lighting circuit, also for bridge
lights. An indicating wattmeter and a voltmeter,
Electrical Instrument Company, or equivalent
Engineers and of the capacity called for on the
and mounted on the switchboard. All switchb
essary for the satisfactory operation of the electr
in these specifications shall be furnished, wheth
or not, and bidders will submit with their

of the appurtenances included. One set of extra carbons for each kind of circuit breaker and ten extra fuses of each kind used shall be furnished.

All switches, circuit breakers, and other appurtenances shall have ample capacity for the greatest current the motors may use.

P. 115. *Grounds*

All ground connections to the structure shall be made with proper soldered terminals secured to a copper plate of ample area fastened to the return street railway circuits. Care shall be taken to locate the connections so that there shall be ample metal and proper circuits to return the current without damage to the structure. Ground trolleys, similar to the feeder trolley, shall be placed at both ends of the fixed structure. They shall have ample ground-connection separate from the structure.

P. 116. *Solenoid Brake*

Each motor shall be supplied with a standard solenoid brake of the same manufacture as the motor, mounted on the armature shaft and supported on the steel work. The brake shall be released on the first point of the controller and applied when the current is turned off, the motor being started on the second point of the controller. The brake shall be of ample capacity to brake the motor efficiently. One (1) extra spool, two (2) extra shoes, and six (6) extra springs for the solenoid brake shall be furnished.

P. 117. *Limit Switches*

Suitable limit switches shall be supplied and shall be so arranged that the electric current will be automatically cut off and so that the solenoid brake will be applied to the motor governed by it, when the movable span approaches either limit of its motion. The limit switch shall be so constructed that the point of cut-off shall be positive but adjustable by the operator. A suitable short-circuiting spring switch shall be furnished and placed convenient to the operator, so that power may be supplied to the motor after the limit switches have operated.

V. 118. *Service Lights and Roadway Lights*

Wherever a movable span is employed, it is necessary to provide service lights in the machinery house, operator's house, gate tenders' houses, and stairs, and at other points on the span where machinery or walkways to the machinery are to be found. The current for the service lighting system is generally taken from the feeders for the operating machinery. Where highway traffic crosses a structure, roadway lights are generally used. This is invariably the case on city bridges. Either one or both of these lighting systems may be required, depending on the nature of the structure; and this clause must be written with that in

[illegible] preferable for [illegible]
[illegible] of the span and the service [illegible]
[illegible]

This clause should give the system [illegible]
and in the latter case the number of [illegible]
[illegible] the number and type of lamps, the [illegible]
kind of wire and conduits for wire, [illegible]
and all details necessary for the complete [illegible]
system should be specified. Usually, [illegible]
and for the service system, and these are [illegible]
so that each lamp will have the proper voltage.

EXAMPLE (SERVICE LIGHTS)

There shall be placed in each machinery [illegible]
sixteen (16) c.-p. lights disposed about the [illegible]
and there shall be placed ten (10) sixteen [illegible]
among the outside machinery and at stair landings [illegible]
the lights on the stairs to be controlled by a [illegible]
well as on the switchboard.

In each gate-tender's house there shall be placed [illegible]
c.-p. lights; and on each of the four roadway gates [illegible]
five (5) sixteen (16) c.-p. lights with red globes. [illegible]
shall have weatherproof sockets. Each set of [illegible]
by proper switches on adequate switchboards.

All lamps, globes, sockets, wires, cut-outs, [illegible]
tenances necessary for the complete operation of [illegible]
be provided. The wiring shall be run in loricated [illegible]
conduits approved by the Engineers; and these [illegible]
fastened to the structure. All wires shall be [illegible]
covered, copper wire, none of which shall be smaller [illegible]
gauge. They shall be drawn into the conduits without [illegible]
wire or its insulation, and all joints in the wire shall [illegible]
and double-taped with rubber tape and friction tape.

EXAMPLE (ROADWAY LIGHTS)

The bridge shall be illuminated by tungsten [illegible]
clear glass globes, fourteen (14) inches in diameter [illegible]
contain two one-hundred (100) watt tungsten [illegible]
sockets, suspended from a bracket attached to [illegible]
rubber bushing shall be used in attaching the lamp [illegible]

[illegible] any jar or vibration caused by [illegible]

[illegible] system shall be three (3) wire, two hundred and [illegible] volts, with one hundred and ten (110) volts between the neutral and either outside wire. A connection to the source of supply shall be provided at each end of the bridge. A control box shall be placed at each source of supply and shall contain the necessary switches and fuses to protect and control the lights. Between the control box and the feeding device there shall be placed a lightning arrester, a pole switch, and a fuse, mounted on a non-absorbent, non-combustible, insulating-base and enclosed in a weather-proof box.

Thirty-six (36) lights, four (4) on each span, each containing two (2) lamps, are required.

The wiring shall be run in loricated pipe conduits, or other conduits approved by the Engineers; and these conduits shall be securely fastened to the structure. All wires shall be double-braided, rubber-covered copper wire, none of which shall be smaller than No. 12 B. & S. gauge. They shall be drawn into the conduits without injury to either the wire or its insulation, and all joints in the wire shall be cleaned, soldered, and double-taped with rubber tape and friction tape.

All lamps, globes, sockets, wires, cut-outs, conduits, and other appurtenances necessary for the complete operation of the lighting system shall be provided. All work shall conform to the National Electric Code for [illegible] particular class of work, and all materials and workmanship shall be first-class in every respect, and subject to the inspection and approval of the Engineers.

EXAMPLE (ROADWAY LIGHTS)

The structure is to be illuminated by an electric lighting system. [illegible] shall be furnished and installed all lamps, globes, conduits, wiring, [illegible] all other apparatus and appurtenances necessary for a complete series [illegible] Lighting System, taking current from the Kansas City Electric [illegible] Company's 6.6 ampere constant current feeders at the east end of [illegible] structure. There will be two circuits. The circuit for lighting the [illegible] roadway will have sixty 125 watt, 6.6 ampere, constant-current [illegible] tungsten lamps. Each lamp will be supported on a cast-iron [illegible] and will be surrounded by an opal glass globe 14 inches in diam[illegible]. The circuit for lighting the lower roadway and the stairways [illegible] fifty-six 75 watt, 6.6 ampere, constant-current, series, tungsten [illegible] Each lamp shall be supported on a cast-iron standard or bracket [illegible] be surrounded by an opal globe twelve (12) inches in diameter. [illegible] shall be drawn into Sherardized steel pipe conduits of a satis[illegible] so as to be free from all flaws or mechanical injuries. All [illegible] No. 6 high-tension, lead-covered, okonite, stranded copper [illegible]. The conduit shall be encased in the concrete as the

latter is placed; and it shall be
later the wire may be drawn into
be provided, and all connections
they shall conform properly to the
cuts shall be provided for each light. All
tween pipes and boxes shall be made water
system shall be constructed in a thoroughly
the satisfaction of the Engineers.

V. 119. *Signal and Semaphore*

The United States Government requires
of lights to mark the clear channel for all
the position of the movable span where such a
should specify the requirements for the

EXAMPLE

Signal lights, as required by the United
provided and placed on the piers and the

For the lift span, the following lights shall
of each tower pier there shall be one red light
pier. Vessel signal lamps shall be attached to the
the up- and the down-stream sides of the lift
of a double electric lantern having eight-inch
and red. They shall be wired so as to be
stand to show either green or red; and there shall
operator's house a green and a red lamp so mounted
circuit is glowing.

For the swing span the following lights shall
end of the draw protection, at each end of each
side of the pivot pier, there shall be one red light
the pier. Three signal lamps shall be placed on the
one at each end over the portal and one on the top
each signal consisting of a double electric lantern
lenses colored green and red. They shall be wired
from the operator's stand to show either green or
red lamp so mounted as to denote which circuit is
in the operator's house.

All lights, both red and green, shall be visible
a clear atmosphere at a distance of not less than
are to be shown from half-round, pressed, Fresnel
in diameter with an arc of illumination of one
degrees. The lamps are to be enclosed in
firmly attached as may be approved. The lights
of the channel shall be controlled from the

All lanterns, lamps, sockets, wires, conduits, and other appurtenances necessary for the complete operation of the signal service and semaphore lights shall be provided. The wiring shall be run in loricated pipe conduits or other conduits approved by the Engineers; and they shall be securely fastened to the structure. All wires shall be double-braided, rubber-covered, copper wire, none of which shall be smaller than No. 12 B. & S. gauge. They shall be drawn into the conduits without injury to either the wire or its insulation, and all joints in the wire shall be cleaned, soldered, and double-taped with rubber tape and friction tape.

P. 120. *Indicator Lights for Span Operation*

Signal lamps shall be provided to indicate the open and closed positions of the **locks, end-lifts, gates and span.** They shall be located in the operator's house on the switchboard. They shall show clear when the span is ready for bridge traffic, and shall show red for open positions when the span is closed to traffic. Each indication must be sufficiently accurate to permit safely the carrying out of the succeeding operations.

Adequate contacts, properly insulated, shall be attached to the metalwork as indicated on the drawings, or as may be approved by the Engineers. All wiring for the signal system shall generally conform to the requirements of wiring for the lighting system and shall be carried in approved conduits. The signal lights shall be mounted on a slate panel, and each light shall be properly labeled.

V. 121. *Vessel Signals*

In some localities special signals are required for vessels. Where such is the case, this clause should outline the equipment and installation completely.

EXAMPLE

The movable span shall be provided with a vessel signal to indicate to navigators that their signals have been heard and whether the bridge will be opened. Each signal shall consist of a pole supporting a copper ball twenty-four (24) inches in diameter made of No. 22 gauge copper and painted red. The ball shall be raised or lowered by a tiller rope extending to the operator's stand, and the signal shall be so situated that when the ball is raised it shall be visible to navigators approaching the bridge from either up- or down-stream.

P. 122. *Electric Siren*

For the purpose of signaling approaching vessels, there shall be provided and installed two electric sirens, together with battery, wiring, conduits, push button switch, and all other appurtenances necessary for proper operation. The sirens shall be of such size as to be easily heard

[illegible] shall be attached to the [illegible]
[illegible] equipment and layout shall [illegible]

P. 123. *Signal Bell*

The Contractor shall furnish and install [illegible]
ing in conduits, switches, and all connections [illegible]
bell. The said bell is to be located at about the [illegible]
span, as called for by the plans. It is to be [illegible]
iron base and with all working parts adequately [illegible]
proof case. The gong is to be fifteen (15) [illegible]
of bell metal. The electrical contacts shall [illegible]
be provided in the operator's house an automatic [illegible]
for the bell, so arranged that by pressing the button [illegible]
to ring for twenty (20) seconds and then stop [illegible]
again. The conduits containing the wires shall [illegible]
the steel work, being placed so as to be inconspicuous [illegible]

I. 124. *Machinery House Crane*

The Contractor shall furnish and put in place [illegible]
as per the detailed plans, a .... ([illegible]
crane with suspended, four-wheel trolley, equipped [illegible]
(......) ton Yale and Towne Triplex Hoist, or other [illegible]
the Engineers.

P. 125. *Interlocking Apparatus*

There is to be an approved system of interlocking [illegible]
of bridge traffic, for which drawings are to be prepared [illegible]
for the Manufacture of the Metalwork and submitted [illegible]
gineers for their approval before work upon it is started.

P. 126. *Gasoline Engines*

Gasoline engines of the size and make specified, [illegible]
equivalent engines acceptable to the Engineers, shall [illegible]
and properly connected with the machinery. Each [illegible]
of developing an amount of brake horse-power ten (10) [illegible]
of the rated capacity when operating at the normal [illegible]
gasoline as fuel. It shall be tested at the manufacturer's [illegible]
this condition before shipment.

Each engine shall be furnished with a magneto [illegible]
switchboard, oiling devices, carburetors, tanks for [illegible]
air-pump, air-compressor, piping, wiring, wrenches [illegible]
sories necessary for starting and for successful operation [illegible]

P. 127. *Installation of Machinery*

All machinery and machinery parts shall be prepared, erected, adjusted, painted, oiled, and put in perfect operating condition. If the Contractor **for Erection** have any objection to any features of the machinery, as designed, he must state his objections in writing to the Engineers within ten days after signing his contract; otherwise his objections will be ignored, if offered later as excuse for defective erection, adjustment, or operation. The Contractor **for Erection** shall furnish grease for guides, oil for machinery, and all such supplies to complete the mechanical parts for operation. The Contractor **for Erection** shall also maintain all machinery in adjustment and shall perform all labor and operate the bridge for the Purchaser's service for a period of sixty (60) days after it has been accepted by the Purchaser and put into service, without additional payment. The Purchaser will furnish the necessary gasoline and oil for such operation.

P. 128. *Paint*

The paint for the metalwork shall be Detroit-Superior Graphite, Nobrac, the Goheen Carbonizing Coating, red lead, or any other paint which the Engineers shall name, it being understood that the paint to be used shall be that chosen by the Engineers after the contract is let, and that if the said paint cost the Contractor more than **one dollar and fifty cents ($1.50)** per American gallon delivered at the works of the Manufacturers of the metalwork, or at the bridge site, the Contractor shall be paid extra the actual excess cost of the paint over **one dollar and fifty cents ($1.50)** per American gallon.

P. 129. *Painting*

All metalwork, before leaving the shop, shall be thoroughly cleansed from all loose scale, rust, and dirt, and shall be given one coat of red lead ground in linseed oil, or any other priming coat required by the Engineers, which coat shall be thoroughly dried before the metalwork is loaded for shipment. It is absolutely essential that the entire surface of the metalwork be thoroughly cleansed by the most effective known methods, such as the use of wire brushes and scrapers. All surfaces coming in contact shall be particularly well painted before being riveted together. Bottoms of bed-plates, bearing-plates, and any other parts which are not accessible for painting after erection shall have three (3) coats of paint, one at the shop, the other two in the field, before erection. Pins, bored pinholes, turned friction-rollers, and all other polished surfaces shall be coated with white lead and tallow before shipment from the shop. Graphite or oil should be used as the lubricant for reaming; but should soap-suds be employed, all parts of the metal affected thereby must be washed thoroughly and dried before any painting is done thereon.

After the structure is
cleansed from mud, grease, or any
be found upon it, the rivet-heads and
damaged shall be painted, then the entire
and evenly covered with two (2) coats of the
coats of paint given to the metal work are to
shades or colors; and the second coat must be
before the third coat is applied. No thinning
benzine, or other thinner will be allowed without
sion from the Engineers. No painting is to be
weather, unless it be under cover where the
freezing point.

All painting is to be done in a thorough and
the satisfaction of the Engineers, and no paint
the structure without first being approved by the
materials for painting shall be subject at all times to the
and chemical analysis; and the detection of any
material, in either shop or field, shall involve the
suspected material at hand and the scraping and
tions of the work which, in the opinion of the Engineers,
painted on account of such inferior material.

All recesses which would retain water or through
enter must be filled with thick paint or some water
receiving final painting. All surfaces so close together
insertion of paint brushes must be painted thoroughly
of cloth instead of the brush.

P. 130. *Timber*

All timber remaining permanently in the structure
quality, sawed true and out of wind, and free from
loose knots, decayed wood, worm holes, or any other
opinion of the Engineers, would impair its strength or
less it be used under water, not more than ten (10)
of any stick at any cross-section shall be sap wood.
permanently under water shall be first-class,
All timber and lumber shall be surfaced on all four
form to the net dimensions specified on the draw
timber by the thousand feet B. M., only the actual
in place will be allowed for, notwithstanding trade
contrary, and bidders should figure accordingly.

All timber left in the structure above low wat
yellow pine, Douglas fir, cedar, or other first-cl
satisfactory to the Engineers. Timber left perma
may be of any variety which, in the opinion of the
and of adequate strength.

I. 131. *Preservation of Timber*

All treated timber is to receive .... (......) pounds of creosote oil per cubic foot. The process of treatment shall be such that the wood is first softened and the saps and resins dissolved by steam, then removed from the wood by the application of a vacuum, after which the creosote oil shall be injected by pressure until the amount required above has entered the pores of the wood. The oil used shall be the best obtainable grade of coal-tar creosote; that is, it must be a pure product of coal-tar distillation, and must be free from admixture of oils, other tars, or substances foreign to pure coal-tar; it must be completely liquid at thirty-eight (38) degrees Centigrade, and must be free from suspended matter; and the specific gravity of the oil at thirty-eight (38) degrees Centigrade must be at least 1.03. When distilled according to the common method, that is, using an eight (8) ounce retort, asbestos covered, with standard thermometers, bulb one-half (½) inch above the surface of the oil, the creosote, calculated on the basis of the dry oil, shall give no distillate below two hundred (200) degrees Centigrade, not more than five (5) per cent below two hundred and ten (210) degrees Centigrade, and not more than twenty-five (25) per cent below two hundred and thirty-five (235) degrees Centigrade. The residue above three hundred and fifty-five (355) degrees Centigrade (if it exceeds five (5) per cent in quantity) must be soft. The oil shall not contain more than three (3) per cent of water.

If practicable, all timber to be creosoted shall be cut to exact dimensions before being treated, so that it will fit into position without trimming at the site. Any creosoted timber that has to be cut after treatment must have the cut surfaces thoroughly covered with hot asphaltum before being placed in position.

V. 132. *Track-Rails and Their Connections*

This clause shall state whether rails are to be provided for steam or electric railway, or both, and shall give the standard used and the section number, weight, length, and process of manufacture. It also shall give complete details as to splices, bolts, spikes, bonds, tie-bars, and all other appurtenances necessary for the complete installation of the track.

EXAMPLE

The railway track rails shall be of the A. S. C. E. section weighing eighty (80) pounds per yard; and the street railway track rails shall be of the Lorain Steel Company's Section 79, No. 373, weighing seventy-nine (79) pounds per yard, or other rails of equivalent section and weight which are satisfactory to the Engineers. Railway rails shall be made by the open-hearth process.

[illegible] holes in the rails and [illegible] Company's Standard for [illegible] inch in diameter with [illegible] The joints in each [illegible] splice bars, tie bars, bolts, [illegible] every kind shall be made by the [illegible] with the Lorain Steel Company's [illegible] grooved-girder or high tee rails, but the rails [illegible] except when variation from this length is [illegible]

V. 133. *Paving* [illegible]

In this clause the kind of pavement and [illegible] be fully described in every detail. Ordinarily in the [illegible] paving blocks of creosoted, long-leaf, Southern [illegible] West, creosoted Douglas fir; but sometimes [illegible] ment will be called for.

The following are types of the specifications [illegible]

V. 134. *Creosoted Block* [illegible]

This clause should specify the kinds of timber [illegible] the dimensions of the blocks, the amount of creosote [illegible] composition of the creosote and the testing thereof, [illegible] ment, the base, and the cushion or bedding layer [illegible] and it should also give a detailed description of the [illegible] blocks. Only one kind of timber should be permitted [illegible] About eighteen (18) pounds of creosote oil per cubic [illegible] for yellow pine, and twelve (12) pounds for Douglas [illegible]

EXAMPLE

The pavement is to be of creosoted, long-leaf, [illegible] Norway pine, Douglas fir, or tamarack blocks; [illegible] wood is to be used on the structure.

The blocks must be cut from a good grade of [illegible] be well manufactured, full-size, square-butted, [illegible] from the following defects: checks, unsound, loose [illegible] knot-holes, worm-holes, through shakes, and round [illegible] the surface. The number of annular rings in the [illegible] begins one inch from the centre of the heart of the [illegible] than six. In the case the block does not contain the [illegible] to be used shall begin with the annular ring which [illegible] of the heart. No block shall contain less than fifty [illegible] wood.

[illegible] from six (6) to ten (10) inches [illegible] (5) inches. The depths of the blocks shall be [illegible] widths three and a half (3½) inches. A variation [illegible] one-sixteenth ($\frac{1}{16}$) of an inch shall be allowed in either the [illegible] or the thickness from the dimensions specified.

[illegible] The preservative to be used shall be a product of coal gas or coke-oven tar, which shall be free from all adulterations and shall contain no raw or unfiltered tars, petroleum-compounds, or tar-products obtained from processes other than those stated. The specific gravity shall not be less than one and eight-hundredths (1.08) nor more than one and fourteen hundredths (1.14) at a temperature of thirty-eight (38) degrees Centigrade. Not more than three and one-half (3.5) per cent shall be insoluble by continuous hot extraction with benzol and chloroform.

On distillation, which shall be made exactly as described in Bulletin No. 65 of the American Railway Engineering Association, the distillate based on water-free oil shall be within the following limits, and an average of a number of tests shall show a mean of these percentages, viz.:

Up to 150 degrees Centigrade	....	Nothing must come off
" 170 " "	....	0 to 0.5 per cent
" 210 " "	....	2 to 6 per cent
" 235 " "	....	8 to 16 per cent
" 315 " "	....	30 to 45 per cent
" 355 " "	....	45 to 60 per cent

[illegible] The specific gravity of the distillate distilling between 235 degrees and [illegible] degrees Centigrade shall not be less than one and two-hundredths [illegible] at sixty (60) degrees Centigrade compared with water at the same temperature.

[illegible] The preservative shall not contain more than three (3) per cent of water.

[illegible] The manufacturer of the blocks shall permit full and complete sampling at all times and places, and shall, if required, furnish satisfactory proof of the origin of the preservative.

[illegible] The blocks shall be treated in an air-tight cylinder with the preservative hereinbefore specified. They shall be subjected to steam at a temperature between 220 and 240 degrees Fahrenheit, after which a vacuum [illegible] than twenty (20) inches shall be drawn, the temperature at [illegible] time being maintained at from 150 to 240 degrees Fahrenheit. [illegible] vacuum is still on, the preservative oil, heated to a temperature [illegible] 170 and 200 degrees Fahrenheit, shall be admitted, and the [illegible] shall be gradually applied until a sufficient amount of the pre[illegible] has been forced into the blocks. Not more than ten (10) [illegible] excess above the amount specified shall be allowed. The [illegible] treatment, shall show satisfactory penetration of the pre[illegible] and through; and all blocks that have been warped, [illegible] otherwise injured in the process of treatment shall be rejected.

The surface of the blocks shall be
or other foreign substances.

The blocks shall be inspected at the
the blocks shall equip his outfit with all the
and facilities to enable the Inspector to satisfy
points of the specifications are fulfilled.
representative of the Engineers to inspect all
plant during the manufacture of the paving blo

After delivery at site the blocks shall be
tion, and all imperfect blocks shall be rejected
Contractor.

The base of the pavement shall be of concrete
ings, finished off smooth on top to correct
be covered to a depth of about one-eighth (⅛)
with hot asphaltum as the blocks are laid.

Upon the bed thus prepared the blocks shall
fibre of the wood vertical in straight, parallel
one row of blocks shall be placed parallel with the
(¾) of an inch therefrom.

The blocks shall be laid by setting them loosely
coat, but no joint shall be more than one-eighth
cepting that on grades of three (3) per cent or over,
(⅜) by one and one-quarter (1¼) inch creosoted
structure shall be placed between the lines of
the said cushion. None but whole blocks shall be
or completing a course or in such other cases as
and in no case shall the lap joint be less than
shall be carefully cut and trimmed by experienced
the blocks used for closure must be free from check
cut end must have a surface perpendicular to the
cut to the proper angle to give a close, tight joint
to be thoroughly covered with hot asphaltum before

Along the curb there shall be one or more
with hot asphaltum, the total width of the said
curb being one-half (½) inch for each ten feet of
This is to be done in order to provide against a
of the pavement due to the blocks drying and after

After the blocks are placed, they shall be rolled
to the curb by a steam roller weighing at least
becomes smooth and is brought truly to the
After the blocks have been thoroughly rolled,
shall be filled half way up with hot asphaltum,
shall be filled with hot pea-gravel or hot stone
employed, or otherwise with hot, fine, screened
shall again be rolled.

After inspection by the engineers, the surface of the wood-block pavement shall be covered to a depth of about one-half (½) inch with fine screened sand. This sand is to be left upon the pavement for such time as may be directed by the Engineers, after which it shall be swept up and taken away by the Contractor.

The Contractor will be required to give a guarantee, satisfactory to the Purchaser, that the preservative used will keep the blocks free from decay for a period of ten (10) years, and to furnish, free of charge at the bridge site, an adequate number of paving blocks to replace all those which shall decay wholly or in part within ten (10) years from the date of the completion of the bridge.

V. 135. *Asphalt Pavement*

This clause should give complete specifications for all the materials entering into the pavement and for its construction. The total thickness of the binder and the wearing surface will depend on the traffic crossing the structure as well as on the length of the span when it is necessary for economy to keep down the dead load. This thickness will vary from two (2) inches for long spans and light traffic to three and one-half (3½) inches for short spans and heavy traffic. The greater thickness is preferable whenever funds are available for its adoption.

EXAMPLE

Description.—The pavement shall consist of, first, a concrete base as shown on the drawings; second, a binder course one and a half (1.5) inches in thickness when compressed; and, third, an asphalt wearing surface two (2) inches in thickness when compressed.

Foundation.—The concrete for the foundation shall be mixed as hereinafter specified, the upper surface being parallel to and three and a half (3.5) inches below the finished surface of the paving. After being laid, the surface of the concrete shall be protected from rain, if necessary, and shall be sprinkled with hose and rosehead sprinkler as frequently as may be required by the Inspector until it is sufficiently set.

Materials.—The materials used for the binder and wearing courses must comply with the requirements of these specifications, and must be mixed in definite proportions by weight. All materials and the proportions thereof used must be satisfactory to the Engineers.

Methods of Testing.—All tests must be conducted as hereinafter specified. All penetrations at 77 degrees Fahrenheit are expressed in hundredths of a centimeter and are to be taken (except where otherwise specified) with a No. 2 needle acting for five (5) seconds without appreciable friction under a total weight of one hundred (100) grams.

Refined Asphalts.—The refined asphalts admitted under these specifications shall be prepared from a natural mineral bitumen, either solid or

[illegible] [illegible] and [illegible] shall be subject to such [illegible] as the Engineer may [illegible] under these specifications [illegible] in quality to the recognized [illegible] asphalt. If desired, the Contractor [illegible] at the refinery. To be acceptable [illegible] with the foregoing general requirements [illegible] requirements *a*, *b*, *c*, *d* and *e* for asphalt

Asphalt obtained by the refining of [illegible] be reduced in the refining process to a [illegible] less than 30.

All refined asphalts admitted under these [illegible] with the following requirements:

a. All shipments of refined asphalt of any [illegible] number plainly marked on each package or [illegible] in consistency and composition, and shall not [illegible] minimum more than fifteen (15) points in

b. Ninety-eight and one-half (98½) per cent [illegible] all refined asphalts shall be soluble in carbon

c. When made into an asphalt cement by [illegible] and methods as are described in these specifications [illegible] an asphalt cement complying with all the [illegible] forth herein for asphalt cements.

Fluxes.—These shall be the residues obtained [illegible] paraffine, asphaltic petroleums, or semi-asphaltic [illegible] be of such character that they will combine with [illegible] to form an acceptable and approved asphalt cement [illegible] requirements of these specifications. All residua [illegible] ing general tests:

a. They must have a penetration greater than [illegible] fifty (350) with a No. 2 needle at 77 degrees F. [illegible] weight for one second.

b. They shall have a specific gravity at 77 [illegible] and 1.02.

c. When twenty (20) grams of the flux are [illegible] at 325 degrees F. in a tin box two and one-quarter [illegible] and three-quarters (¾) of an inch deep after [illegible] prescribed, the loss shall not exceed five (5) per [illegible] residue left after such heating shall flow at 77

d. They shall not flash below 350 degrees F. [illegible] oil tester.

[illegible] soluble in carbon tetrachloride [illegible] (99) per cent.

[illegible]—This shall be clean, hard, broken stone, free from [illegible] that have been weathered or are soft. If the stone does [illegible] the proper amount of material passing the one-half (½) [illegible] the deficiency may be made up by the addition of gravel or [illegible] (95) per cent of the binder aggregate shall pass a [illegible] circular openings the diameter of which shall be three-quarters of the thickness of the binder course to be laid. The remaining (5) per cent shall not exceed in their smallest dimension the thickness of the binder course to be laid. The binder aggregate shall be so graded [illegible] coarse to fine as to have the following mesh composition (sieves [illegible] used in the order named):

Passing 10 mesh	15 to 35%
Passing ½ inch circular opening and retained on 10 mesh	20 to 50%
Total passing ½ inch	35 to 85%

(N. B.). The above limits as to mesh composition are intended to provide for such permissible variations as may be rendered necessary by the [illegible] sources of supply and the character of the work to be done. The [illegible] composition and character of the stone may be varied, within the [illegible] above specified, at the discretion of the Engineers, depending upon [illegible] kind of asphalt used and the traffic conditions.

Sand.—The sand shall be hard, clean grained, and moderately sharp. [illegible] it shall have the following mesh composition (sieves to be used [illegible] order named):

Passing 200 mesh	0 to 5%
Passing 100 mesh and retained on 200 mesh	10 to 25%
Passing 80 mesh and retained on 100 mesh	6 to 20%
Passing 50 mesh and retained on 80 mesh	5 to 40%
Passing 40 mesh and retained on 50 mesh	5 to 30%
Passing 30 mesh and retained on 40 mesh	5 to 25%
Passing 20 mesh and retained on 30 mesh	5 to 15%
Passing 10 mesh and retained on 20 mesh	2 to 10%
Passing 8 mesh and retained on 10 mesh	0 to 5%
Total passing 80 mesh and retained on 200 mesh	20 to 40%
Total passing 20 mesh and retained on 40 mesh	12 to 45%

[illegible] light traffic a coarser sand may be used with the approval [illegible], but in no case shall a sand be employed that contains [illegible] total of fifteen (15) per cent passing an 80-mesh sieve, such [illegible] not more than five (5) per cent (calculated on the original [illegible] 200-mesh sieve, or a mixture of seventy-five (75) per cent [illegible] character above specified and twenty-five (25) per cent of

[illegible]
10-mesh screen, may be [illegible]
(M. B.) The above limits as to [illegible]
for such permissible variations [illegible]
able sources of supply and the [illegible]
composition and character of the [illegible]
above specified, at the discretion [illegible]
kind of asphalt used and the traffic [illegible]
Filler.—This shall be thoroughly dry [illegible]
equally satisfactory stone, or Portland [illegible]
pass a 30-mesh-per-lineal-inch screen [illegible]
shall pass a 200-mesh-per-lineal-inch [illegible]
contain from 6 to 20 per cent of this filler [illegible]
sand and asphalt used and the traffic conditions [illegible]

Samples.—One (1) pound samples of the [illegible]
and asphalt cement that the Contractor [illegible]
together with a statement as to the source, [illegible]
of the materials composing them, must be [illegible]
no contract shall be awarded to any bidder [illegible]
in every respect with these specifications. [illegible]
specified in his bid shall be used by any Contractor [illegible]
consent of the Engineers, and provided that [illegible]
with the requirements of these specifications.

In addition to the samples submitted with [illegible]
taken from and actually representative of the [illegible]
flux, sand, filler, and binder stone to be used [illegible]
be submitted to the Engineers before the use of such [illegible]
is permitted. Except at the option of the Engineers [illegible]
or surface shall be commenced within three weeks [illegible]
such samples were submitted; and in no case shall [illegible]
have been examined and approved by the Engineers [illegible]
the course of the work, new deliveries of paving [illegible]
the Contractor, samples of these shall at once be [illegible]
gineers; and their use in the work will not be permitted [illegible]
examined and approved by the said Engineers.

Asphalt Cement.

Preparation.—The asphalt cement shall be [illegible]
phalt—or asphalts and flux, where flux is required [illegible]
where herein specified, and it must be of a suitable [illegible]

The proper proportions of the refined asphalt [illegible]
shall be melted together at a temperature between [illegible]
and thoroughly agitated by suitable appliances [illegible]
blended into a homogeneous asphalt cement. [illegible]
cement must not be heated to a temperature exceeding [illegible]

asphalt cement contains material that will separate by subsidence when it is in a molten condition, it must be thoroughly agitated before using from storage and while in use in the supply kettles. Excessive agitation with steam or air which will injure the cement must not be permitted.

The refined asphalt or asphalts and flux comprising the asphalt cement shall, when required, be weighed separately in the presence of the authorized Inspectors or agents of the Engineers.

Requirements.—The asphalt cement shall comply with the following requirements:

a. It shall be thoroughly homogeneous.

b. It shall have a penetration at 77 degrees F. of from 30 to 55 for heavy traffic and 55 to 85 for light traffic, depending upon the sand and asphalt used and the local climatic conditions.

c. It shall not flash below 350 degrees F. when tested in a closed oil-tester.

d. When twenty (20) grams of the asphalt cement are heated for five (5) hours at 325 degrees F. in a tin box two and one-quarter (2¼) inches in diameter and three-quarters (¾) of an inch deep, after the manner hereinafter prescribed, the loss shall not exceed five (5) per cent. by weight; and the penetration at 77 degrees F. of the residue left after such heating must not be less than one-half the penetration at 77 degrees F. of the original sample before heating.

e. Either the asphalt cement or its pure bitumen when made into a briquette (Dow mold) shall, at 50 penetration (77 degrees F.), have a ductility of not less than 30 centimetres at 77 degrees F.; the two ends of the briquette to be pulled apart at the uniform rate of 5 centimetres per minute.

When the asphalt cement as used has a penetration other than 50 at 77 degrees F., an increased ductility of 2 centimetres will be required for every five points in penetration above 50 penetration, and a corresponding reduction will be made below 50 penetration.

[illegible]

[illegible]

Preparation.—The binder shall be composed of stone, or stone and sand, and asphalt cement of the character elsewhere herein specified and mixed in proper proportions. The stone, or stone and sand, and the asphalt cement shall be heated separately to such a temperature as will give, after mixing, a binder mixture of the proper temperature for the [illegible] employed. The stone when used must be at a temperature [illegible] and 350 degrees F. The asphalt cement and the stone shall be [illegible] mixed by machinery until a homogeneous mixture is produced, [illegible] the particles are thoroughly coated with asphalt cement.

[illegible] The binder mixture prepared in the manner above described [illegible] to the work in wagons covered with canvas or other

[illegible] site it shall at once be [illegible] spread roughly in place by means [illegible] uniformly spread by means of hot [illegible] thoroughly compacted by tamping or [illegible] binder shall average one and a half [illegible] a forty (40) per cent variation from the [illegible] be permitted at any one spot. The [illegible] shall lie parallel to the established grade [illegible] surface after compression shall show at [illegible] cement; for any spot showing such [illegible] with other material. All binder that [illegible] any way defective or which may become [illegible] with wearing surface must be taken up and [illegible] replaced by good material properly made and [illegible] specifications, at the expense of the Contractor [illegible] be laid at any one time than can be covered [illegible] ing plant on surface mixture. Binder when [illegible] covered with wearing surface as soon as is [illegible] the most thorough bond between the binder and [illegible] binder course shall be kept as clean and as [illegible] under working conditions. If necessary, it [illegible] before laying the wearing surface on it.

No binder shall be laid when, in the [illegible] weather conditions are unsuitable, or unless the [illegible] to be laid is free from pools of water and has set [illegible]

Requirements.—The finished binder must [illegible] seven (7) per cent of bitumen soluble in cold [illegible] fifteen (15) to thirty (30) per cent of material [illegible] and from twenty (20) to fifty (50) per cent of [illegible] half (½) inch screen, the percentage of bitumen [illegible] cordance with the mesh composition and character [illegible] gate of the binder, and the percentage of material [illegible] screen to be regulated in accordance with the traffic [illegible] roadway to be paved.

Wearing Surface.

Preparation.—The wearing surface shall be [illegible] and asphalt cement of the character elsewhere [illegible] in proper and definite proportions by weight. [illegible] cement shall be heated separately to such a [illegible] after mixing, a surface mixture of the proper [illegible]

employed. The sand when used must be at a temperature between 275 and 375 degrees F. The asphalt cement when used must be at a temperature between 250 degrees F. and 350 degrees F. The various ingredients shall be brought together and mixed for at least one minute in a suitable apparatus until a homogeneous mixture is produced, in which all the particles are thoroughly coated with asphalt cement. The weights of all materials entering into the composition of the wearing surface shall be verified in the presence of Inspectors as often as may be required, and the Engineers or their representatives shall have access to all parts of the plant at any time.

Laying.—The surface mixture prepared in the manner above described shall be brought to the work in wagons covered with canvas or other suitable material, and upon reaching the site shall have a temperature between 230 degrees F. and 350 degrees F. The temperature of the surface mixture within these limits shall be regulated according to the temperature of the atmosphere, the working of the mixture, and the character of the materials employed. On reaching the site, it shall at once be dumped on a spot outside of the space on which it is to be spread. It shall then be deposited roughly in place by means of hot shovels, after which it shall be uniformly spread by means of hot iron rakes in such a manner that after having received its final compression by rolling, the finished pavement shall conform to the established grade. The thickness of the finished surface mixture shall average two (2) inches. Not more than a ten (10) per cent variation from the average thickness specified will be permitted in any one spot. Before the surface mixture is placed, all contact surfaces of curbs, man-holes, etc., must be well painted with hot asphalt cement. After raking, the surface mixture shall at once be compressed by rolling or tamping, after which a small amount of cement shall be swept over it, and it shall then be thoroughly compressed by a steam roller weighing not less than two hundred (200) pounds to the inch width of tread, the rolling being carried on continuously at the rate of not more than two hundred (200) square yards per hour per roller, until a compression is obtained which is satisfactory to the Engineers. Such portions of the completed pavement as are defective in finish, compression, or composition, or that do not comply in all respects with the requirements of these specifications, shall be taken up, removed, and replaced with suitable material, properly made and laid in accordance with these specifications, at the expense of the Contractor. Whenever so ordered by the Engineers, a space of twelve (12) inches next to the curb shall be coated with hot asphalt cement, which shall be ironed into the pavement with hot smoothing irons.

No wearing surface shall be laid when, in the opinion of the Engineers, the weather conditions are unsuitable, or unless the binder on which it is to be placed is dry. Excessive use of water on the steam roller when compressing the pavement will not be permitted. The finished pave-

[illegible]

[illegible] must be well
is in proper condition for the

Requirements.—The finished pavement
composition and bitumen contents within
be used in the order named):

Bitumen........................
Passing 200 mesh........................
Passing 80 mesh........................
Passing 50 mesh........................
Passing 40 mesh........................
Passing 30 mesh........................
Passing 20 mesh........................
Passing 10 mesh........................
Passing 8 mesh........................
Total passing 200, 100, and 80 mesh........
Total passing 50 and 40 mesh........
Total passing 30, 20, and 10 mesh........

(N. B.) The minimum amount of bitumen
tures containing the minimum total passing the 80
of bitumen must be increased above the minimum
80 mesh increases. On pavements subjected to
the Engineers have approved the use of a
that specified for general use, the surface mixture
than six (6) per cent of mineral matter passing a
less than a combined total of eighteen (18) per
100, and 80 mesh sieves. The maximum amount
mesh material will be regulated according to the
phalt used and the traffic upon the structure on
to be laid, subject to the maximum requirements
under sand and filler.

(N. B.) The above limits as to mesh composition
men are intended to provide for such permissible
dered necessary by the raw materials used and by the
to be done. The composition of the wearing surface
the limits above specified at the discretion of the
upon the kind of sand. filler, and asphalt used and

Condition at Expiration of Guarantee.

In addition to the proper maintenance of the
period of guarantee, the Contractor shall, at his
the expiration of the guarantee period, make
necessary to produce a pavement which shall:

a. Have a contour substantially conforming
as first laid and free from depressions of any kind

(3/8) of an inch in depth as measured between any two points four (4) feet apart on a line conforming substantially to the original contour of the street.

b. Be free from cracks or depressions showing disintegration of the surface mixture.

c. Contain no disintegrated surface mixture.

d. Not have been reduced in thickness more than three-eighths (3/8) of an inch in any part.

e. Have a foundation free from such cracks or defects as will cause disintegration or settling of the pavement or impair its usefulness as a roadway.

Repairing.

Repairs, except as provided for below, shall in all cases be made by cutting out the defective binder and wearing surface down to the concrete and replacing them by new and freshly prepared binder and wearing surface made and laid in strict accordance with these specifications.

Whenever any defects are caused by the failure of the foundation, the pavement (including such foundation) shall be taken up and relaid with freshly prepared material made and laid in strict accordance with these specifications.

In all cases the surface of the finished repair shall be at the grade of the adjoining pavement and in accordance with the contour of the roadway.

The surface heater method of repairing may be used only in those cases where the repairs are not rendered necessary by:

a. Failure of concrete.

b. Failure of the binder.

c. Failure caused by the disintegration of the lower portion of the wearing surface.

Whenever the surface heater method is employed, all defective surface shall be removed before replacing it with new material. In all cases the old surface shall be removed to a depth of not less than one-quarter inch; and the new surface must, when compressed, be not less than one-half in thickness. The heat shall be applied in such a manner as not to injure the remaining pavement. All burnt and loose material shall at once be completely removed, and, while the remaining portion of the old pavement is still warm, shall be replaced by new and freshly prepared wearing surface made and laid in strict accordance with these specifications.

With the written permission of the Engineers, not to exceed twenty (20) per cent of crushed old asphalt surface mixture of suitable character may be used in combination with the binder stone, provided that such mixture produces a binder complying in all respects with the requirements of these specifications.

The following methods
[illegible] test is made
the American Society for Testing
Penetration Test.—Penetrations shall
apparatus which shall be so constructed
hundredths of a centimetre the depth to
needle will penetrate the sample under
without appreciably retarding friction for

For penetrations at 77 degrees F. the
seconds and the total weight operating on the
(100) grams, except in the case of flux where
second and the total weight fifty (50) grams

The samples to be tested should, preferably
about two and one-quarter (2¼) inches in
quarters (¾) of an inch deep (2-ounce Gill
American Can Company). Where very soft
or penetrations are to be taken at 100 degrees
tin not less than two (2) inches deep and having
fied above should be used.

All samples shall be melted at a temperature
render them liquid (250 to 300 degrees F.)
oughly stirred until homogeneous and free from
sufficiently in the air at laboratory temperature
for at least thirty (30) minutes in water maintained
at which the test is to be made (77 degrees F.)
sample shall be accurately maintained at the

The average of from three (3) to five (5)
more than five (5) points (five-hundredths (0.05) of
maximum and minimum shall be taken as the
the needle being wiped off with a dry cloth after

(N. B.) This test measures the consistency of
amination. Its limits of accuracy may be considered
(5) per cent of the reading obtained (above or below

Ductility Test.—This test is usually first made
itself. If this fails to show the required ductility,
be extracted and tested. The proper methods for
bitumen vary with the asphalt being examined and
description here. (See *Proceedings* of American
terials, vol. 9, pages 594–9.)

The moulding of the briquette may be done
The mould should be placed upon a brass
asphalt from adhering to the plate and the inner
able pieces of the mould, they should be well

[illegible] together in a [illegible] [illegible]. The material to be tested is poured [illegible] and while in a molten state, a slight excess being added to [illegible] on cooling. After the briquette is nearly cool, it is [illegible] level by means of a heated palette knife. When cooled, the [illegible] off and the two side pieces removed, leaving the briquette [illegible] firmly attached to the two ends of the mould, which thus serve [illegible]. The briquette should be immersed in water maintained at the [illegible] temperature for at least thirty (30) minutes or until the whole [illegible] of bitumen is at 77 degrees F. It is then pulled apart at the [illegible] rate of speed in a suitable machine, the briquette being entirely [illegible] in water maintained at 77 degrees F. during the entire [illegible] of pulling. Any pieces of dirt, wood, or extraneous matter in the [illegible] may cause the fracture of the fine thread before the true [illegible] ductility of the material under examination has been reached. [illegible] care should be observed, therefore, to avoid the presence of such [illegible] matter in the bitumen when it is poured into the mould. The [illegible] of at least two tests shall be recorded as the ductility of the sample [illegible] examination. These tests must not differ more than twenty (20) [illegible] from their average.

(N. B.) This test measures approximately the cementing value of a [illegible], but is not necessarily a measure of the relative cementing value of [illegible] bituminous materials or the same bituminous material at different [illegible]. Its limits of accuracy may be considered as being within [illegible] (20) per cent of the reading obtained (above or below).

[illegible] *of Total Bitumen in Refined Asphalts and Asphalt Cements.* [illegible] two grams of the sample shall be weighed into a tared 200 c.c. [illegible] Erlenmeyer flask and covered with 100 c.c. of chemically pure [illegible] bisulphide. Agitate until all lumps disappear and nothing ad- [illegible] the bottom of the flask. Cork and allow to stand fifteen (15) [illegible]. Filter off on a Gooch crucible with asbestos felt or a weighed [illegible] and wash until the washings come through practically colorless. [illegible] and filter at 250 degrees F. Evaporate the filtrate con- [illegible] bitumen, burn to an ash and add to the residue on the filter.

[illegible] B.) The limits of accuracy of this test as applied to bitumens con- [illegible] proportions of non-bituminous matter may be con- [illegible] within one-half (½) per cent above or below the result [illegible] In practically pure bitumens one-quarter (¼) per cent above or [illegible] ordinary limit of accuracy.

[illegible] *of Bitumen Soluble in Carbon Tetrachloride.*—One gram [illegible] shall be weighed into a tared 200 c.c. wide mouth Erlen- [illegible] covered with 100 c.c. of chemically pure carbon tetra- [illegible] until all lumps disappear and nothing adheres to the [illegible]. Cork and allow to stand eighteen (18) hours in the [illegible] a Gooch crucible with asbestos felt or a weighed

filter paper and wash until the
[illegible] not less than 165
degrees F.

(N. B.) The amount of bitumen
indicative of whether or not decomposition
heat treatment. The limits of accuracy of
as being within one-half (½) per cent

Volatilization Test.—Twenty (20) grams
in a weighed tin box two and one-quarter
quarters of an inch high (two-ounce Gill-style
American Can Company) and heated five (5)
The heating shall be done in a ventilated oven
the temperature specified before the introduction
which is maintained within two (2) degrees of the
out the test. The tin can should be insulated
other material from direct metallic contact with
oven. The bulb of the thermometer should be
bath immediately alongside of the sample being
and the method of insulation being the same

(N. B.) This test indicates the extent to which
of time lose their more volatile hydrocarbon constituents
resulting from volatilization and chemical change
as an accelerated exposure test. Its limits of
itely stated, owing to the widely varying results
different types of ovens and failure carefully to
prescribed. When carefully conducted according
a test showing six (6) per cent loss should be
specification calling for not over five (5) per cent

Flash Test.—The flash test shall be made in
two and one-quarter (2¼) inches in diameter
eighths (1⅜) inches deep (3 ounce Gill-style,
provided with a suitable transparent cover of
cover shall be provided with two apertures for the
mometer and test flame. The aperture for the
three-eighths (⅜) of an inch in diameter and
The aperture for the test flame shall be triangular
one-half (½) inch on the base and three-quarters
The base shall coincide with the rim of the can.
mately fifteen (15) inches long, graduated in single
bulb completely immersed in the material being
touch the bottom of the can, but shall be suspended
tion. The can shall be filled with the material to
a one-half (½) inch vapor space when melted
heated at the rate of ten degrees F. a minute,
be applied every five degrees F. after a temperature

has been reached. No correction for emergent stem shall be made. The test flame shall be one-eighth (1/8) of an inch long, and shall be dipped in just below the surface of the cover and then immediately withdrawn.

(N. B.) This test indicates the temperature at which inflammable vapors are given off in an enclosed space. It supplements the volatilization test and guards against the use of a material containing too large an amount of volatile hydrocarbons. Its limit of accuracy may be considered as being five (5) degrees above or below the reading obtained.

Specific Gravity Test.

a. Fluid materials: The specific gravity of fluid materials shall be taken in the usual way in a picnometer at 77 degrees F.

b. Viscous fluid and semi-solid materials: The specific gravity of these materials shall be taken in a cylindrical, weighing-bottle picnometer.

c. Hard solid materials: The specific gravity of hard, solid materials shall be taken by the displacement method.

Determination of Bitumen Contents and Mesh Composition of Binder.

Weigh out from 350 to 500 grams of the binder and extract the bitumen from it in a centrifugal extractor or suitable continuous hot extractor, using chemically pure carbon bisulphide as a solvent for the bitumen. Follow the same general method for the drying and sifting of the mineral aggregate as described in the method for analyzing surface mixtures. The sieves to be used are as follows:

1¼-inch, 1-inch, ¾-inch, and ½-inch circular openings, and 10-mesh.

(N. B.) The limits of accuracy of this test are as follows:

For bitumen contents, three-tenths (3/10) per cent above or below the result obtained. For mesh composition, ten (10) per cent of the result obtained (above or below).

Determination of Bitumen Contents and Mesh Composition of Surface Mixtures.

The sample of surface mixture should be heated to about 300 degrees F. until soft, and ten to twenty grams of it should be weighed on to a tared S. & S. filter paper No. 595, 11 cms. in diameter. The filter paper and contents should be placed in a funnel and washed with chemically pure carbon bisulphide until the washings run through practically colorless. Dry the filter paper and residue at 250 degrees F. for one-half (½) hour. Open the filter paper carefully and remove the mineral aggregate. Scrape off the dust adhering to the paper as thoroughly as possible with a blunt palette knife and add it to the mineral aggregate. Evaporate the filtrate containing the bitumen, burn the bitumen, add the filter paper to it and burn to an ash. Add the ash to the mineral aggregate previously removed from the filter paper and weigh. The difference between the weight of surface mixture originally taken and the combined weight of

[illegible]

[illegible] calculated: [illegible]
[illegible] 100, 80, 50, 40, 30, 20, 10,
[illegible] shall be continued [illegible]
[illegible] through the sieve during

If desired, the surface mixture may
any suitable form of extractor with hot
and the combined ash from the extracted
gate sifted as above.

(N. B.) The limits of accuracy of
For bitumen contents, three-tenths
result obtained. For mesh composition,
obtained (above or below).

Samples.

Samples should be put in clean, dry
or cans. The following amounts of the
for tests:

Binder stone..............................
Filler......................................
Sand.......................................
Refined asphalt..........................
Asphalt cement..........................
Flux..

Method of Sampling.

Extreme care should be taken in every case to
is truly representative of the material to be
precautions to be observed in each case are given

Binder Stone.

A sufficient number of five-pound samples to
parts of the pile. These should be thoroughly
duced by quartering to the desired size.

Filler.

A sample should be taken from several bags,
should be mixed.

Sand.

Samples should be taken from the interior of
is damp. A sufficient number of one-pound
from different parts of the pile. These should
together and reduced by quartering to the desired

Refined Asphalt and Asphalt Cement.

In barrels: At least one sample should be taken from each batch. It should be secured at sufficient depth below the surface to insure obtaining representative material free from all dirt or other extraneous matter.

In tank cars: The contents of the tank should be heated until completely liquid throughout. It should then be agitated and thoroughly mixed by means of air or steam, after which the sample may be taken in any convenient manner.

In kettles: The contents of the kettles must be completely liquid and thoroughly agitated previous to and during sampling. The sample may be taken from the pipe through which the material is delivered to the mixer or by means of a clean dipper.

Flux.

The directions given for sampling refined asphalt and asphalt cement apply to this material, except that under ordinary conditions it is not necessary to agitate the contents of the tank car.

Surface and Binder Mixtures.

Samples should, preferably, be taken on the structure after the mixture has been shoveled and raked. Samples taken from the plant shall be obtained from the wagons, special care being observed to avoid material from the top of the load or which appears to vary from the average. Samples should be pressed between sheets of paper and trimmed while hot to a convenient size.

P. 136. *Bitulithic Pavement*

Description.—On a properly prepared concrete base, as shown on the drawings, shall be laid the wearing surface or pavement proper, which shall be composed of carefully selected, tough, sound, hard, crushed limestone, mixed with bitumen and laid as follows:

After heating the stone in a rotary mechanical dryer to a temperature of about 280 degrees Fahrenheit, it shall be elevated and passed through a rotary screen, having six or more sections with varying sized openings, the maximum of which shall be 1¾ inches, and the minimum of which shall be one-tenth ($^1/_{10}$) of an inch in diameter. The several sizes of stone thus separated by the screen sections shall pass into a bin containing six sections or compartments. From this bin the stone shall be drawn into a weigh-box resting on a scale having seven beams. The stone from each bin is accurately weighed in the proportion which has been previously determined by laboratory tests to give the best results; that is, the most dense mixture of mineral aggregate, and one having inherent stability. From the weigh-box, each batch of mineral aggregate, composed of differing sizes accurately weighed as above, shall pass into a "twin pug" or other approved form of mixer. In this mixer shall

be added a sufficient quantity of
Water-proof cement, varied from
or other similar compound
quantity to coat thoroughly all the
in the mixture. The bituminous
stone, be heated to between 200 and 250
for each batch shall be accurately
proportion as has been previously
tion to give the best results and to fill the
The mixing shall be continued until the
minous concrete. In this condition it shall
there spread on the prepared foundation
ough compression with a steam roller, it
(2) inches. The proportioning of the varying
ous cement shall be such that the
as practicable, have the solidity and density of

Surface Finish.—After rolling the wearing
over it, while it is still warm, a thin coating
Bituminous Flush Coat Composition, or other
able to the Engineers, by means of a suitable
chine, so designed as to spread quickly over the
ness of the said Flush Coat Composition.
be provided with a flexible spreading band and
regulating, to any desired amount, the quality
composition to be spread. On grades of over 4
Coat may be used in place of the liquid Flush Coat

While the Flush Coat Composition is still warm,
over it, in at least two coats, fine particles of hot
cient quantity completely to cover the surface
stone chips shall be spread by means of a
chine, so designed as to provide a storage
cubic feet capacity, and rapidly and uniformly to
pavement with the desired quantity of stone.
shall be provided with an adjustable attachment
the quantity of stone spread at each operation.
immediately and thoroughly rolled into the
cool. The purposes of the Flush Coat Composition
of hot crushed stone are not only to fill any uneven
also to make the said surface waterproof and gritty,
foothold for horses. The size of the stone chips
direction by the Engineers; and they are to be of
stone specified for the wearing surface.

The roller used for compressing the wearing
the stone chips shall be operated by steam power
pressure of not less than 250 pounds per lineal

Each layer of the work shall be kept free from dirt, so that it will unite with the succeeding layer. The amount of bituminous cement to be used for coating the heated stone for the wearing surface shall be varied as the Engineers may direct, in order to suit the varying volume of voids in the aggregate. The bituminous composition shall be free from water, petroleum oil, water-gas, tar, or inferior process tars; and it shall be especially refined in order to remove the light volatile oils and other matter susceptible to atmospheric influences. The cut-back process shall not be used in making the bituminous cement.

If the fine-crushed stone used does not provide the best proportions of fine-grained particles, these must be supplied by the use of hydraulic cement, pulverized stone, or very fine sand, as the Engineers may direct; but the amount thereof shall in no case exceed fifteen (15) per cent of the total mass.

V. 137. *Brick Paving*

In the following example, Portland cement grout, coal-tar paving-pitch, and asphalt joint fillers are included; but usually only one kind will be used in any one specification.

EXAMPLE

Character of Brick.—All brick must be strictly No. 1 pavers of the sizes commercially known as "vitrified block," and "brick," the widths of which must not vary more than one-eighth (1/8) of an inch. They must be thoroughly annealed, tough, and durable, regular in size and shape, and evenly burned.

When broken, the brick shall show a dense, stone-like body, free from lime, air-pockets, cracks, or marked laminations. They must not be fire flashed, smoked, or treated in any manner tending to give artificially a uniform color outside. Kiln marks must not exceed three-sixteenths (3/16) of an inch in depth and one edge at least shall show but slight kiln marks. All brick so distorted in burning as to lay unevenly in the pavement shall be rejected.

The standard size of brick shall be two and one-half (2½) inches in width, four (4) inches in depth, and eight and one-half (8½) inches in length; and the standard size of block three and one-half (3½) inches in width, four (4) inches in depth, and eight and one-half (8½) inches in length. They shall not vary from these dimensions to exceed one-eighth of an inch in width and depth, and not more than one-half (½) inch in length. If the edges of the brick are rounded, the radius shall not exceed three-sixteenths (3/16) of an inch. Only brick with raised lugs on one side not to exceed one-fourth (¼) of an inch in height shall be used.

Inspection.—All brick shall be subjected to thorough inspection before and after laying and rolling, and all rejected material shall be immediately removed from the site.

Factory inspection of brick including the rattler test, shall be made, if,

[illegible] *of Brick.*—The [illegible]
hand, and neatly piled on the [illegible]
grading is finished; and in laying [illegible]
pavement.

Rattler Test for Block Size.—The [illegible]
than 22 per cent after being [illegible]
however, that brick from any one [illegible]
shall not vary more than eight (8) [illegible]

Samples of brick of uniform [illegible]
from each car tested (estimated at 10,000 [illegible]
that would cull them shall not be used. [illegible]
tested—one of the softest, one of the [illegible]
burned. If all of the tests overrun the [illegible]
shall be rejected. If one or two of the [illegible]
said grade or grades shall be made. Should [illegible]
run the specified percentages of loss, the [illegible]
grade, provided they do not exceed ten (10) [illegible]
brick in the car, and deliver the balance [illegible]
whole carload will be rejected.

In order to prevent the continued [illegible]
cars of two separate shipments of any make of [illegible]
they fail to meet the requirements stated [illegible]
will be rejected.

Number and Condition of Brick.—Ten (10) [illegible]
tute the number to be used in a single test. [illegible]
dried for at least three (3) hours in a [illegible]
degrees Fahrenheit before testing.

Tests before Unloading.—The Contractor shall [illegible]
the location and car number of each carload [illegible]
samples, if deemed necessary, may be taken [illegible]
shall be delivered at or adjacent to the site [illegible]
been received from the Engineers or their [illegible]
they have been superficially inspected or have [illegible]
Decision relative to each carload will be made [illegible]
hours of notice. Permission to deliver brick [illegible]
be considered a final acceptance in any respect.

Making the Rattler Test.

The machine shall be of good mechanical [illegible]
shall conform to the following details of [illegible]
shall consist of barrel, frame, and driving [illegible]

[illegible]—The barrel of the machine shall be made up of the heads, [illegible] and staves.

The heads shall be cast with trunnions in one piece. The trunnion rings shall not be less than two and one-half (2½) inches in diameter less than six (6) inches in length.

The heads shall not be less than three-fourths (¾) of an inch thick more than seven-eighths (⅞) of an inch. In outline they shall be a ular fourteen (14) sided polygon inscribed in a circle twenty-eight and e-eighths (28⅜) inches in diameter. The heads shall be provided h flanges not less than three-fourths (¾) inch thick and extending ward two and one-half (2½) inches from the inside face of head to rd a means of fastening the staves. The flanges shall be slotted on enter edge, so as to provide for two (2) three-fourths (¾) inch bolts ach end of each stave, said slots to be thirteen-sixteenths (13/16) inch and two and three-fourths (2¾) inches from centre to centre. Under section of the flanges there shall be a brace three-eighths (⅜) inch and extending down the outside of the head not less than two (2) es. Each slot shall be provided with a recess for the bolt head, which act to prevent the turning of the same. There shall be for each head iron headliner one (1) inch in thickness and conforming to the out- of the head, but inscribed in a circle twenty-eight and one-eighth inches in diameter. This liner or wear plate shall be fastened to head by seven (7) five-eighths (⅝) inch cap screws through the head the outside. These wear plates, whenever they become worn down half (½) inch below their initial surface level at any point of their ce, must be replaced with new. The metal of which these wear are to be composed shall be what is known as hard machinery iron must contain not less than one (1) per cent of combined carbon. The of the polygon must be smooth and must give uniform bearing for staves. To secure the desired uniform bearing the faces of the head be ground or machined.

The Staves.—The staves shall be made of six (6) inch medium steel ural channels twenty-seven and one-fourth (27¼) inches long and fifteen and five-tenths (15.5) pounds per lineal foot.

The channels shall be drilled with holes thirteen-sixteenths (13/16) of in diameter, two (2) in each end, for bolts to fasten same to head, line of the holes being one (1) inch from either end and one -eighths (1⅜) inches either way from the longitudinal centre [illegible]

spaces between the staves will be determined by the accuracy of , but shall not exceed five-sixteenths (5/16) of an inch. The flat side of each channel must be protected by a lining or wear ths (⅜) inch thick by five and one-half (5½) inches wide by -fourths (19¾) inches long. The wear plate shall con- steel plate and shall be riveted to the channel by three

(3) one-half (½) inch rivets, one of which shall be on the centre line both ways and the other two on the longitudinal centre line and spaced seven (7) inches from the centre each way. The rivet holes shall be countersunk on the face of the wear plate, and the rivets shall be driven hot and chipped off flush with the surface thereof. These wear plates shall be inspected from time to time, and, if found loose, shall be at once re-riveted; but no wear plate shall be replaced by a new one except as the whole set is changed. No set of wear plates shall be used for more than one hundred and fifty (150) tests under any circumstances. The record must show the date when each set of wear plates goes into service and the number of tests made upon each set.

The staves when bolted to the heads shall form a barrel twenty (20) inches long, inside measurement, between wear plates. The wear plates of the staves must be so placed as to drop between the wear plates of the heads. These staves shall be bolted tightly to the heads by four (4) three-fourths (¾)-inch bolts. Each bolt shall be provided with lock nuts and shall be inspected at not less frequent intervals than every fifth (5th) test, and all nuts shall be kept tight. A record shall be made after each such inspection, showing in what condition the bolts were found.

The Frame and Driving Mechanism.—The barrel shall be mounted on a cast-iron frame of sufficient strength and rigidity to support the same without undue vibration. This shall rest on a rigid foundation, and shall be fastened thereto by bolts at not less than four points.

The barrel shall be driven by gearing in which the ratio of driver to driven shall not be less than one (1) to four (4). The countershaft upon which the driving pinion is mounted shall not be less than one and fifteen-sixteenths ($1^{15}/_{16}$) inches in diameter, with bearings not less than six (6) inches in length and belt driven; and the pulley shall not be less than eighteen (18) inches in diameter and six and one-half (6½) inches in face. A belt of six (6)-inch, double-strength leather, properly adjusted so as to avoid unnecessary slipping, shall be used.

The Abrasive Charge.—The abrasive charge shall consist of two sizes of cast-iron spheres. The larger size shall be three and seventy-five hundredths (3.75) inches in diameter when new, and shall weigh then approximately seven and five-tenths (7.5) pounds (3.40 kilos) each. Ten shall be used.

These shall be weighed separately after each ten tests, and if the weight of any large shot falls to seven (7) pounds (3.175 kilos) it shall be discarded and a new one substituted; provided, however, that all of the large shot shall not be discarded and new ones substituted at any single time, and that so far as possible the large shots shall compose a graduated series in various stages of wear.

The smaller size sphere shall be, when new, one and eight hundred and seventy-five thousandths (1.875) inches in diameter, and shall weigh not to exceed ninety-five hundredths (0.95) of a pound (0.430 kilo) each.

Of these spheres so many shall be used as will bring the collective weight of the large and small spheres most nearly to three hundred (300) pounds, provided that no small sphere shall be retained in use after it has been worn down so that it will pass a circular hole one and seventy-five hundredths (1.75) inches in diameter drilled in a cast-iron plate one-fourth (¼) inch in thickness, or if it weigh less than seventy-five hundredths (0.75) of a pound (or 0.34 kilo.). Further, the small spheres shall be tested after every ten tests, by passing them over such an iron plate drilled with such holes, or by weighing, and any which pass through the holes or fall below the specified weight shall be replaced by new spheres; provided, further, that all of the small spheres shall not be rejected and replaced by new ones at any one time, and that so far as possible the small spheres shall compose a graduated series in various stages of wear.

If at any time any sphere is found to be broken or defective it shall at once be replaced.

The iron composing these spheres shall have a chemical composition within the following limits:

Combined carbon..................	Not less than 2.50 per cent
Graphite carbon..................	Not more than 0.10 per cent
Silicon..........................	Not more than 1.00 per cent
Manganese........................	Not more than 0.50 per cent
Phosphorus.......................	Not more than 0.25 per cent
Sulphur..........................	Not more than 0.08 per cent

For each new batch of spheres used the chemical analysis must be furnished by the maker, or be obtained by the user, before introduction into the charge; and unless the analysis meets the above specifications, the batch of spheres shall be rejected.

The Test.—The rattler shall be rotated at a rate of not less than 29½ nor more than 30½ revolutions per minute, and 1,800 revolutions shall constitute the standard test. A counting machine shall be attached to the rattler for counting the revolutions.

A margin of not to exceed ten revolutions will be allowed for stopping. In case a charge is allowed to run several minutes beyond its proper termination, and the loss incurred is still within the prescribed limits, then the test shall not be discarded, but the fact shall be entered on the record.

Stopping and Starting.—Only one start and stop per test is regular and acceptable. If from accidental causes a test is stopped and started twice extra, and the loss exceeds the maximum permissible, the test shall be disqualified, and another shall be made.

The Results.—The loss shall be calculated in percentage of the original weight of the dried brick composing the charge. In weighing the rattled brick, any piece weighing less than one (1) pound shall be rejected.

[illegible]

[illegible] by means of a [illegible] all entries are made [illegible] shall be removed and the [illegible] All calculations must be made in the [illegible] printed blank and the actual figures [illegible] the serial number and be filled out [illegible] as to dates of inspections, weighing of [illegible] parts must be carefully entered, so that [illegible] shall constitute a continuous one. In [illegible] being needed, they may be furnished [illegible] shall the original carbon copy be removed [illegible]

The blank form upon which the records [illegible] be kept and reported is as follows:

REPORT OF STANDARD RATTLER [illegible]

[illegible]

Name of firm furnishing sample.................... [illegible]
Name of the firm manufacturing sample.................... [illegible]
Bridge or job which sample represents.................... [illegible]
Brands or marks on the brick.................... [illegible]
Quantity furnished.................... [illegible]
Date received.................... [illegible]
Length.................. Breadth.................. [illegible]

Standardisation Data

Number of charges tested since last inspection.................... [illegible]
....
....
Weight of charge (after standardisation).................... [illegible]
Condition of locknuts on staves.................... [illegible]
Condition of scales.................... [illegible]
Ten large spheres.................... [illegible]
Small spheres.................... [illegible]
Total.................... [illegible]
Number of charges tested since stave linings were renewed [illegible]
Repairs (Note any repairs affecting the condition of the [illegible]

Running Data

Time readings—Hour.............. Minutes.............. [illegible]
Revolution counter readings.............. Running [illegible]
Beginning of test.................... [illegible]
Final reading.................... [illegible]

Weights and Calculations

Initial weight of ten bricks.................... [illegible]
Final weight of same.................... [illegible]
Loss of weight.................... Percentage [illegible]
Note: (The calculations must appear).................... [illegible]
....
....

Number of broken bricks and remarks on same..................................

I certify that the foregoing test was made under the specifications of............. and is a true record.

Signature of tester......................

Date............................... Location of Laboratory.............

....

....

Construction of the Pavement.

Foundation.—The foundation shall be a concrete base as shown on the drawings.

Sand Cushion.—Over the foundation, which must be thoroughly cleaned, shall be spread to a uniform depth of one and one-half (1½) inches (after rolling) a cushion of clean, sharp sand, free from foreign matter, except that it may contain not to exceed 10 per cent of loam. The sand must be fairly well graded from one-quarter (¼) inch to that which will be retained on No. 50 standard mesh sieve. The word "sand" includes broken stone or slag meeting the specified grading.

The cushion shall be carefully shaped to a true cross-section of the roadway by means of a template having a steel-faced edge, covering at least one-half (½) the width of the brickwork, and so fitted with rollers as to be easily drawn on the curb and guide timbers or rail.

Template.—The template shall be built in substantial accordance with the plans.

Guide Timbers.—Guide timbers shall be one and one-half (1½) inches by four (4) inches by sixteen (16) feet, dressed on two sides, laid to a true surface in the centre of the street, and also next to the curb if the curb cannot be used.

Shaping Cushion.—Before shaping the cushion, one-half (½) inch strips shall be laid on the curb and guide timbers, or rail, and the template shall be drawn over the same, after which the one-half (½) inch strip shall be removed, and the cushion shall be slightly moistened and rolled over its entire surface with a hand roller. The roller shall not be less than thirty-six (36) inches in diameter or twenty-four (24) inches in width, and shall weigh not less than ten (10) pounds per inch of width. It shall have a handle twelve (12) feet in length. After rolling, the template shall be drawn over the curb and guide timbers or rail, to complete the cushion, which shall be prepared at least fifty (50) feet in advance of the brick laying.

Laying the Brick.—The brick shall be laid in straight lines on edge, at right angles to the curb. At intersections they shall be laid as directed. Brick shall be laid with the lug sides all in the same direction. Brick must be placed close together, both ends and sides, breaking joints at least three (3) inches. At every fourth course the brick shall be driven together to secure tight joints and straight courses, and all thick brick shall be removed. Brick shall be used with the best edge up. Broken,

chipped, or warped brick, not
batting.

When any section shall contain
the brick shall be taken up and the
laid from curb to curb, or from car track

No bats or broken brick shall be used
tracks. Batting for closures shall immedi

Joints shall be cut square with the top
must be kept clean and open to the bott

Street-Car Tracks.—Along the street-car
laid within one-quarter (¼) of an inch of
be one-quarter (¼) inch below the top of the

The space between the web of the rail and
cement mortar, consisting of two (2) parts of
Portland cement. The mortar shall be in p
shall be constructed to a straight line before the

Expansion Joints for Cement Grout Filler.
placed parallel with and at each of the curb
one-half (1½) inches in width. The joints
together on edge, parallel with the curb, two
(6) inches in width, and dressed on two faces
curb shall be one (1) inch wide on top, bevel
half (½) inch at the bottom, and the strip next
the same dimensions and placed in a reverse p
be laid lightly against said strips. Soon after the
grouted and the cement filler has set, and the
respects finished, the strips shall be removed, the j
out, and immediately completely filled with a bit
of a material which, when penetrated by a No. 2
of 200 grams for one (1) minute at a temperat
have a penetration of not less than 20, and when
needle under 50 grams for five (5) seconds at a
Fahr., will not have a penetration of over 100.

A premoulded expansion strip made of a mate
action of water or street liquids may be used al
meets all the requirements for the joint filler
strips shall not be less than three-quarters (¾)
a thirty (30) foot street or under, increasing
to one and one-half (1½) inches in width for a
over.

Rolling.—After the brick in the pavement have
and the surface swept clean, the pavement shall
weighing not less than three (3) nor more than
lowing manner: The brick next the curb shall
wood tamper to the proper grade. The rolling

curb at a very slow pace, and shall continue back and forth toward centre, until the centre of the roadway is reached; then, passing to opposite curb, it shall be repeated in the same manner to the centre the roadway. After this first passing of the roller the pace may be ickened and the rolling continued until the brick pavement has a smooth rface. The pavement shall then be rolled transversely at an angle of ty-five (45) degrees from curb to curb, repeating the rolling in the posite forty-five (45) degree direction. Before and after this transverse ing has taken place, all broken or injured brick must be taken up and placed with perfect ones. The substitute brick must be brought to true surface by tamping.

After final rolling, the pavement shall be tested with a ten (10) foot ight edge, laid parallel with the curb, and any depression exceeding one-rter (¼) of an inch must be taken out. If necessary, the pavement ll be again rolled.

Portland Cement Grout Filler.—The filler shall be composed of one each of fine, clean, sharp sand and Portland cement. The latter l comply with the standard requirements given elsewhere in this cification.

The sand shall be clean and sharp, fairly well graded from that passing standard sieve to that retained on a 100-standard sieve. Sand shall measured in a box having the same cubical contents as one sack of ent.

Before any grouting is done, a sufficient amount of cement and an amount of sand to complete the work prepared for grouting at time, but not to exceed one-half (½) day's run, shall be thoroughly d dry until the mass assumes a uniform color. From this mixture ount not exceeding two (2) cubic feet shall be taken and placed grouting box, and enough clean water shall be added to obtain a that will penetrate to the bottom of the brick. From the time the is applied until all is removed and floated into the joints of the ment, the mixture must be kept in constant motion. A mechanical approved by the Engineers that will meet these requirements may after the dry mixture of sand and cement has been made. Before out is applied the brick shall be thoroughly wet by being gently [illegible]

water shall be added to this dry mixture in a box preferably four (4) feet eight (8) inches long, thirty (30) inches wide, and (14) inches deep, resting on legs of different lengths, so that will rapidly flow to the lower corner of the box, the bottom shall be about three (3) inches above the pavement. One box used for each fourteen (14) feet in width of roadway, and at boxes must be used in all cases.

shall be removed from the box with scoop shovels and brick in front of the sweepers, who shall rapidly sweep

[illegible]

[illegible] the top.
[illegible] after this application has [illegible]
[illegible] taken place, the pavement [illegible]
squeegees, or wooden scraper, [illegible]
worked over the brick at an angle [illegible]

When completed and after the cement [illegible]
pavement shall be covered with a [illegible]
shall be frequently sprinkled [illegible]
sisted on the pavement for a period [illegible]
grouting, or longer, as the Engineers may [illegible]
conditions.

Ample barricades and watchmen shall [illegible]
for the proper protection to the grouting [illegible]

Coal-Tar Paving-Pitch Filler.—The joints [illegible]
and those between the bricks and the curb [illegible]
holes, etc., shall be filled with coal-tar paving [illegible]
with the following requirements:

Physical Properties.—When in place in [illegible]
such character that it will adhere firmly to [illegible]
curb, and shall be sufficiently plastic to allow [illegible]
expansion of the pavement without developing [illegible]
filler shall be such that it will retain its consist[illegible]
perature. It shall be proof against action by [illegible]
alkalies to which the pavement may be exposed. [illegible]
not be less than 25 per cent, nor more than 40 [illegible]
gravity shall not be less than 1.23 nor more than [illegible]

Melting Point.—It shall have a melting point [illegible]
5° from 135° Fahr., determined by the cube method [illegible]

Method of Use.—The filler shall be heated and [illegible]
to the full depth thereof, at a temperature of not [illegible]
nor greater than 350° Fahr. All joints shall be [illegible]
top. The top dressing of sand shall be spread [illegible]
diately after the filler is applied and while it is still [illegible]
the sand shall be heated so as readily to bond [illegible]
care shall be used at the gutters and around catch[illegible]
to prevent the leakage of water into the sub-road[illegible]

Test for Melting Point of Pitch Filler.—A [illegible]
cube of the pitch is to be formed in a mould and [illegible]
so that the bottom of the pitch to be tested is [illegible]

bottom of the said beaker. The pitch is to remain for five (5) minutes in water of a temperature of 60° Fahr. before heat is supplied. Heat is to be applied in such a manner that the temperature of the water is raised 9° Fahr. each minute. The temperature recorded by the thermometer at the instant the pitch touches the bottom of the beaker is to be considered the melting point.

Asphalt Filler.—The interstices of the brick shall be completely filled with an asphalt filler heated to a temperature of not less than 350° Fahr. nor more than 450° Fahr. This asphalt filler shall not contain pitch nor any part of coal tar. It shall contain at least ninety-eight (98) per cent of bitumen soluble in carbon bisulphide. It shall remain pliable at all temperatures to which it may be subjected as a street paving filler; it shall be absolutely proof against water and street liquids; it shall firmly adhere to the brick and be pliable rather than rigid. Care shall be exercised completely to fill all openings around street structures, and the street shall not be used for traffic until the filler is thoroughly set. A top dressing of sand shall be spread immediately after the filler is applied and while it is still soft.

The penetration shall conform to the following:

No. 2 needle, 5 sec., 100 grams at 77° Fahr., 25 to 60.
No. 2 needle, 1 min., 200 grams at 32° Fahr., not below 25.
No. 2 needle, 5 sec., 20 grams at 115° Fahr., not above 110.

Maintenance.—The period of guaranty shall be five (5) years. During the said period, whenever the surface of a vitrified brick pavement becomes uneven, holding water one-fourth (¼) of an inch or more in depth in a distance of four (4) feet or less, or when the pavement on embankments has settled over trenches existing previous to the completion of the pavement, then the brick shall be taken up and relaid to proper crown and grade.

Any brick which may be found soft, unsound, broken, or disintegrated, and all portions of the pavement which may have become rough by reason of the chipping or breaking of the edges of the brick, so as to produce joints exceeding one-half (½) inch at a point one-quarter (¼) inch below the surface of the brick, shall be removed, and properly replaced with sound material.

P. 138. *Catch-Basins*

At proper intervals, as indicated on the drawings, catch-basins are to be built for the collection of water, which is to be led to the ground from these or discharged into the river by down-spouts.

P. 139. *Down-Spouts*

Down-spouts of the sizes and quality indicated on the drawings are to be provided at the catch-basins. They are to be carried to the ground

encountered by the current
and lead pipes are to be used
to receive injury, and either copper or

V. 140. *Sidewalk*

These should be described thoroughly in
built of reinforced concrete or granitoid; at
Creosoted timber is seldom used for
so much cheaper and because wooden
repaired, almost without interference with
the creosote is very undesirable on a foot
sometimes employed, but they are not as
and it is not likely that they will ever be

The following are types of specifications
usual kinds:

P. 141. *Timber Sidewalk*

The sidewalk floors are to be built of dressed
stantial and thorough manner practicable, in
to the utmost. Wherever timber comes in
or with the steel work, it is to be thoroughly
All holes of any kind which are bored in any
thoroughly saturated with hot asphaltum; and
washers which are to be placed in direct
to be warmed and dipped in a vat of the same

I. 142. *Granitoid Sidewalk*

The sidewalks are to be of reinforced granitoid
(...) inches thick, as is indicated on the drawing
brought to the exact surface required and finished
tions for the granitoid are to be one (1) part of
parts of clean, coarse, sharp sand, and three (3)
broken so small as to pass a one-half (½) inch iron

P. 143. *Expansion Plates for*

At all expansion points, the open spaces in the
are to be covered with steel plates fastened at one
at the other.

P. 144. *Concrete Sidewalk*

Concrete sidewalks on ground or embankment
as follows:

The sidewalks shall not be built until the
soft or unsuitable material found in the sub-grade

the space filled with bank gravel, cinders, or other satisfactory material. The sub-grade shall be compacted and brought to correct elevation by rolling or tamping to the satisfaction of the Engineers. Concrete mixed as herein specified, of proportions one (1) part of cement, three (3) parts of sand, five (5) parts of broken stone or gravel to pass a two and one-half (2½) inch iron ring, shall be placed on the sub-grade, the entire thickness of slab, except the surface finish, being placed at one operation.

The upper portion of the sidewalk slabs, three-fourths (¾) of an inch thick, shall consist of one part of Portland cement to one and one-half (1½) parts of sand. It shall be placed and finished by floating before the mortar in the concrete composing the remainder of the slab has set.

I. 145. *Pavement Base and Curbs on Embankments*

The surface of ground or fill is to be thoroughly rolled and compacted. The rolling is to be done with a roller weighing not less than ten (10) tons, and it is to be continued until the ground shall be brought to conform to the finished grade, being .... (.....) inches lower than the same and parallel thereto. Concrete mixed as herein specified, in the proportion of one (1) part of cement, three (3) parts of sand, and five (5) parts of broken stone or gravel to pass a two and one-half (2½) inch iron ring shall be laid thereon to a depth of .... (.....) inches; and the entire thickness is to be placed at one operation.

The curbs on the street and embankment beyond the ends of the steel work are to be made of concrete as above specified, and finished on the exposed front side and the top with mortar, mixed in the proportion of one (1) part of cement to three (3) parts of sifted sand. The mortar is to be plastered inside the form immediately before the concrete is placed and the top finish is to be put on before the concrete sets hard. The curb is to be cut entirely through, making blocks not exceeding six (6) feet in length. All exposed surfaces shall be carefully finished by troweling to a smooth and even finish; and they must be left free from irregularities and depressions. The angle-iron guard, when called for by the plans, is to be placed as the curb is constructed; and it is to be maintained in position so to be exactly flush with the finished surface of the concrete.

P. 146. *Macadam Pavement*

The surface of the roadway shall be excavated to the depth required by the Engineers, then rolled and compacted with a steam roller weighing not less than ten (10) tons; and, when thoroughly compacted to the satisfaction of the Engineers, it shall be left true to sub-grade, which will be twelve (12) inches below and parallel to the established cross-section of the street, as shown on the accompanying plans. Any soft or spongy ground shall be removed, and such excavation and other depressions as may appear shall be filled with dry earth or broken stone and rolled until

[illegible]
[illegible] immediately upon the
may occur. If at the date named
the Purchaser will accept it and
If it is not in proper condition, the Cont
tions as the Purchaser may deem necessary
before final acceptance and the consequent

P. 148. *Filling of C*

All boxed spaces at column feet of
painted and after the paint has dried, are to
grouting, mixed in the proportion of one (1)
of sand. If the Engineers so permit, two
gravel may be mixed with the grouting,
large.

P. 149. *Timber Construct*

The framing of all timber is to be done
carpenters, with neat joining and tight fitting
work must be done in the most substantial
cable. Ample numbers of fastenings, as called
may be required by the Engineers, are to be
all parts.

All timber bolts are to be of soft steel and
gonal heads and nuts and U. S. standard thread

Wherever timber comes in contact with other
work it shall be thoroughly coated with hot asph
are bored in the timber are to be effectively
bolts and washers which are to be placed in direct
are to be warmed, then dipped in hot asphaltum.

P. 150. *Machinery and Shelter Houses of T*

All materials used in the construction of the
shelter houses shall be of the best quality. All
seasoned material, conforming to the preceding
timber, except that the rough floors and the first
ond quality material. All mill-work shall be of
and finished. The windows shall be of double-
with sash weights and proper catches. The doors
mitered construction one and three-quarters (1¾)
be provided with satisfactory hinges and locks.

Houses shall be built on nailing strips bolted
floors shall be not less than two and one-half (2½
rial sized to thickness, on which shall be laid
ing two (2) inches thick and surfaced on one side
two (2) by six (6) inches, unless otherwise noted

with one (1) inch plank sized to thickness, placed diagonally on the studding and covered with building paper and with approved German drop siding. The inside of studding and ceiling joists shall be covered with three-quarter inch tongued-and-grooved ceiling. Adequate bridging and bracing shall be used as may be directed. Galvanized iron gutters and down spouts shall be provided to take all water from roofs and carry it below the roadways. The rafters shall be sheathed with one (1) inch dressed plank and covered with first class standing-seam tin roofing, to the satisfaction of the Engineers. One coat of approved paint shall be applied to the underside of the tin before laying, and the finished roof shall be painted with two coats of approved paint. Ridges shall be finished with galvanized iron ridge rolls, No. 18 gauge. There shall be provided an approved terra cotta flue and a chimney properly placed and supported; and a stove and piping shall be furnished and set up.

All enclosed or covered structural steel in houses shall receive the full specified painting before the houses are built. All houses shall be painted within and without with a coat of filler and two coats of first-class house paint of colors to be selected by the engineers.

P. 151. *Machinery Houses and Shelter Houses of Fireproof Construction*

The machinery houses and shelter houses are to be of truly fireproof construction, consisting of steel frames, **reinforced-concrete or metal** floors, and approved metal lath and plaster walls and roof. The steel used therein will be paid for at the same price as the other carbon steel **of the river spans,** and the floors, walls, roofs, windows, and doors will be paid for at **the schedule rates (or by the lump sum)** named therefor in the Contractor's tender. The windows and doors are to be built in the best practicable manner according to the detailed plans; and the Contractor will be expected to furnish at his own expense all necessary materials and fittings of best quality and to the satisfaction of the Engineers. The roof shall be covered with tarred felt of the best quality, put on in the usual manner and to the satisfaction of the Engineers. There shall be provided an approved terra cotta flue and a chimney properly placed and supported; and a stove and piping shall be furnished and set up.

P. 152. *Permanent Stairways, Runways, Platforms, Etc.*

The Contractor shall furnish all the materials for and shall build complete all permanent stairways, runways, and platforms, painting all woodwork with filler and two coats of paint, all in accordance with the plans furnished and with the instructions given by the Engineers.

P. 153. *Smoke Protectors*

As shown on the drawings, the smoke protectors shall be constructed with metal lath and Portland cement mortar, mixed in the proportion of one (1) part of cement to two (2) parts of sand.

[illegible] to be placed with [illegible] as may be directed by the [illegible] be put on and all holes filled [illegible] to be thoroughly and carefully [illegible] Two (2) spikes in every [illegible] shall be five and one-half (5½) inches [illegible] inch square. The joints in each

V. 155. Bonding

This clause should specify the type [illegible] of placing them. The cross-bonds [illegible] as the provision to be made for [illegible] movable span is encountered.

Example

The rails are to be bonded by the use of [illegible] bonds, similar to Bond No. 7193 of the [illegible] eighths (⅞) inch terminals and 4-0 cable [illegible] under the angle bars at each joint of each [illegible] properly compressed into freshly drilled holes [illegible] bonds of 4-0 cable with similar terminals are to [illegible] the rails of each track not more than five hundred [illegible] of similar size are to be placed around all special [illegible] the rails in a workmanlike manner to the satis[illegible] All bonds are to be furnished and placed by the

V. 156. *Railway Deck*

This clause should state who must furnish the [illegible] and who is to place them.

Example

The Contractor shall furnish and put in place [illegible] the Engineers, all the materials required for the

V. 157. *Conduits and Gas Pipes for Lighting*

Reference should be made to the drawings, [illegible] layout for the conduits and gas pipes for the lighting [illegible] points between which the conduits and gas pipes [illegible] placed. The sources of supply should be noted [illegible] each conduit should be specified, and all details

[illegible] providing any drawing of the wires [illegible] [illegible]. The location of junction and switch boxes [illegible] specified.

EXAMPLE

Loricated pipe conduit of one inch internal diameter shall begin at each light bracket and extend down the post to a control box provided in the base. From each of these boxes a conduit is to extend under the sidewalks to similar conduits running the full length of the bridge. Beyond the superstructure these conduits are to be attached to the retaining walls below the sidewalks. All connections are to be made so that wires connecting all light brackets can later be easily drawn into the conduits. Junction boxes shall be provided, one being placed at the top of each post. All joints in the pipe and joints between pipes and boxes shall be made watertight. Boxes in bases of posts are to have neat, cast-iron, hinged doors provided with locks.

Gas piping is to be provided and located as described for the conduits. Each pipe is to project upward to the top of the light post and be there supplied with a cut-off valve. All gas pipe is to be of single strength [illegible] inch internal diameter, free from all flaws, and joined and fitted up in such a manner that no leakage of gas can occur. Each exposed end of pipe shall be covered with a cap.

V. 158. *Lamp-posts*

This clause should specify the material from which the lamp-posts are to be made; for instance, cast iron, bronze, or concrete, also the requirements as to fittings, connections, finish, and workmanship in general. The drawings should be referred to for details and dimensions, unless a post of standard make is to be employed, in which case this fact should be stated.

EXAMPLE

All lamp-posts shall be of cast iron of best quality. They shall be smooth and neat in finish and of the dimensions called for on the drawings. They shall be firmly bolted to the hand rail posts (unless they themselves act in that capacity), and a lead gasket shall be placed beneath them to ensure perpendicularity and to keep the iron from staining the concrete.

V. 159. *Carrying of Water-Pipes*

This clause should refer to the drawings for the location of the water-[illegible] and should specify the size, kind, and number of lines of pipe to [illegible]. The points between which the pipes are to be furnished [illegible] the Contractor should be given, as well as the sources of [illegible] for expansion and contraction under temperature

[illegible]

[illegible] the pipes are liable to freezing, [illegible]
be stated.

[illegible]

As shown on the drawings, the [illegible]
pipes over the structure. These pipes [illegible]
be so connected as not to permit of [illegible]
they are to be protected against freezing, [illegible]
provision is to be made for their [illegible]
of temperature.

V. 160. *Pipe Line for* [illegible]

There shall be given here a general [illegible]
indicating the source of supply, the [illegible]
length, size, and character of the pipe [illegible]
character of the pipe on the bridge, as [illegible]
and attaching it to the structure.

As an example the following is quoted [illegible]

DESCRIPTION

The source of supply will be the Leavenworth [illegible]
of which passes through the yard of the engine [illegible]
This main is to be cut for the insertion of a Tee, from [illegible]
inch line running eastward in a straight line some [illegible]
feet till it reaches the brow of a hill, where it will [illegible]
line diagonally down the slope to the western [illegible]
is to be located. The total length of four (4) inch [illegible]
and eighty (780) feet. There will be one horizontal [illegible]
whole length of four (4) inch pipe line. These curves [illegible]
stances will permit.

After leaving the meter the diameter of the pipe will [illegible]
It will pass from the western approach onto the bridge, [illegible]
being blocked up therefrom so as to rise at the rate of [illegible]
(500) to the middle of the main span, after which it will [illegible]
the east end of the eastern span is reached. It will then [illegible]
wagon-way to the railway trestle, after reaching which [illegible]
upper surface of the ties, upon which it will rest outside [illegible]
to same, extending to within fifty (50) feet of the end of [illegible]
of two (2) inch pipe will be about twenty-six hundred and [illegible]

SPECIFICATIONS FOR PIPE [illegible]

It is the intent and purpose of the following [illegible]
necessary to make the pipe-work and other apparatus [illegible]
be omitted in these specifications which is necessary for [illegible]
line, the same shall be supplied by the Contractor [illegible]

UNDERGROUND PIPE

The......(....) inch pipes shall be of cast iron [illegible]
pressure of......(....) pounds per square inch [illegible]

[illegible] lengths of not less than ......(....) feet, and shall have good, strong, grooved bells, with seats at least..........(....) inches in depth. All pipes shall be of uniform thickness, free from lumps or fins on the inside, and they shall have a uniform circular interior surface. The weight of a...........(....) inch pipe shall be........ (....) pounds per lineal foot, no variation from this weight exceeding five (5) per cent being allowed. All pipe shall be made of select grades of pig iron, which in broken sections of pipe shall show a sharp, gray fracture. The use of scrap in making the pipe will not be permitted. The Contractor shall be required to furnish a written guarantee of the makers of the cast iron pipe and special castings to the effect that the said pipe and specials have been subjected to an hydraulic pressure of.......... (....) pounds per square inch and have, at the same time, withstood a careful hammer test made with a heavy sounding hammer. Any lengths of pipe which show damage in handling or shipping shall be rejected. When, in the prosecution of the work, it becomes necessary to cut pipe, the ends of the pipe so cut shall be chiseled off smooth, and with the plane of the face at right angles with the axis of the pipe.

Laying Pipes in Trenches

All pipe must be fitted on the surface of the ground to insure proper jointing, and when laid in the trench shall be true to line and grade. A pit under each joint shall be excavated of sufficient depth and width to admit of thorough caulking of the joints, which must be done with proper tools. Every joint must be packed with oakum and lead, the lead joint to be not less than two (2) inches in depth; and, when caulked, it shall be water tight. In laying, the axes of the adjoining sections shall be in the same straight line; and the pipe, when laid, shall rest upon an oval bed, excavated in the trench for its reception.

Special Castings for Pipes

Special castings shall be of best quality of gray iron, the use of scrap not being permitted. They shall have all turns or corners moulded off to easy curvature, and shall be smooth on inner surface, with clear openings not less than the diameter of the connecting pipe. The weight of the..Tee shall not be less than............(....) pounds.

Gate Valves

There shall be two gate valves in the...........(....) inch pipe line, one located a few feet from the initial point, and the other a few feet from the meter. They shall be iron-bodied, of the double gate pattern, of the sliding type, and of neat workmanship and strongly built; and they shall be provided with composition stems and bell [illegible]. All faces and seats shall be of non-corrosive metal. Both valves shall be cased up to the surface of the ground with............(....) inch iron casing, and shall be capped with adjustable bonnet or cover having a movable lid. Three (3) valve keys shall be furnished for each valve.

Meter

The meter to be used shall be a............(....) inch Standard Crown Meter, set in a thorough manner inside of a circular pit well lined with a concrete wall at least ....(....) inches thick. The top of the pit is to be provided with a cast iron cover plate and frame. The internal diameter of the pit is to be............(....) feet, and that of the opening at the surface of the ground............(....) feet.

Trenches

[illegible] are to be dug as narrow as practicable, and in no case less than four [illegible] feet deep. Should rock be encountered in the trenches (which is

[illegible]

[illegible] valve shall be provided so as [illegible] line on the structure.

The pipe on the structure shall be of steel [illegible] ....(....) inches. It shall be of standard [illegible] being connected by sleeve couplings with screw [illegible] filled with pure asphaltum.

VALVES ON BRIDGE

Once in about every one hundred (100) feet [illegible] there shall be placed, opening upward, a.......... [illegible] or Lunkenheimer gate valve with a two (2) inch hose [illegible] hose to be quickly and effectively attached; all to be [illegible] place.

FASTENING OF BRIDGE

The pipe on the structure shall be firmly attached [illegible] ments shall be made for expansion and contraction, [illegible] of one (1) inch in every one hundred (100) feet. [illegible] ....(....) expansion joints, located as shown [illegible] joints shall be of approved pattern and make, and [illegible] sleeves.

LINEN HOSE AND BOXES

There shall be provided............(....) pieces of [illegible] hose of the best quality, each............(....) feet long, [illegible] coupling and three-quarter (¾) inch nozzle complete. [illegible] provided and secured in place (the positions being shown [illegible] wooden box with a good lock. The locks on all the boxes [illegible] (....) keys must be furnished.

PAINTING THE PIPE LINE

All pipe work and fittings, whether under ground or [illegible] coated on both outside and inside with pure asphaltum [illegible]

MATERIALS AND LABOR ON PIPE LINE

All materials used shall be of the best quality of their [illegible] labor shall be performed in a thorough and workmanlike [illegible]

TEST OF PIPE LINE

After the completion of the work, the entire pipe line [illegible] Engineers, and shall be tested by turning the water on. The [illegible] complete until after the pipe line has been in use two (2) [illegible] before the expiration of such time shall be remedied by [illegible] charge, to the complete satisfaction of the Engineers.

V-181. *Waterproofing*

In this clause should be stated the parts of the structure to be waterproofed and the method to be employed for each particular part. A waterproofing mat is generally specified and its make-up and construction should be clearly indicated. A standard waterproofing material that has proved its effectiveness should be specified with the proper provision for adopting any other waterproofing material that meets the approval of the Engineers.

EXAMPLE

Waterproofing under Ballast.

The surfaces of the slabs and of the faces of curbs up to the top of the ballast are to be waterproofed by the following method: On the clean, dry surface of the concrete there shall be applied with brushes a coating of Sarco concrete primer or any other primer satisfactory to the Engineers, which coating, as applied, shall be thin enough to penetrate the recesses of the concrete, forming an anchorage for subsequent waterproofing. After the priming coat has dried, there shall be applied with mops a heavy coating of Sarco No. 6 waterproofing pitch (or similar waterproofing pitch satisfactory to the Engineers) which has been heated to a temperature of 400° Fahrenheit; and, while this material is still hot, there shall be placed upon it a layer of eight (8) ounce, open-mesh burlap carefully laid down, free from folds or pockets, and with edges lapped at least four (4) inches and sealed with waterproofing pitch. The surface of this burlap shall be heavily swabbed with the waterproofing pitch specified, and a second layer of eight (8) ounce, open-mesh burlap shall be laid in the same manner, making a two-ply burlap mat thoroughly saturated, cemented, and bonded together into the concrete with the waterproofing pitch. Another coating thereof shall be applied as before, and on this coat there shall be placed a layer of asphaltic felt, weighing not less than fourteen (14) pounds per hundred square feet, with edges lapped at least four (4) inches and sealed with waterproofing pitch. The surface of the felt shall then be swabbed with the said pitch and covered with a one-inch thickness of Sarco Mastic, or other asphaltic mastic satisfactory to the Engineers. This shall be carried up the curb walls to the top of the ballast so as to protect the waterproofing mat against punctures from the rock ballast. The surface of this mat shall be heavily swabbed with the pitch specified, and shall be given a sand finish while the material is still hot. Proper joints connecting the waterproofing to the curb and to the expansion joints shall be made as may be directed.

[illegible] under Wood Block Pavement.

[illegible] the clean and dry surface of the concrete slabs and curbs there shall [illegible], with brushes, a coating of Sarco concrete primer, or other

[illegible]
concrete primer satisfactory to the
shall be thin enough to penetrate
anchorage for the waterproofing
dried, there shall be applied with
waterproofing pitch (or other waterproof
Engineers) which has been heated to a tem
and while this layer is still hot, there shall be
(8) ounce, open-mesh burlap carefully
pockets, and with the edges lapped at least
with waterproofing pitch. The surface of
swabbed with the said pitch; and while the
be placed on it one layer of asphaltic felt,
(14) pounds per hundred square feet, with
inches and sealed with waterproofing pitch.
then be heavily swabbed with the said pitch and
the material is still hot. This surface shall be
the pavement is in place. Proper joints
to the curbs and at the expansion joints of the
as may be directed.

P. 162. *Erection of Steel*

The Contractor for Erection shall furnish
barges, and equipment, and shall erect, adjust,
work. Attention is called to the fact that, before
all trusses and towers are to be assembled and
all field connections in the floor system are to be
are assembled, or by using an accurate steel template
columns, and similar members are to be match
erected in accordance with such marking. The
furnish and supply without charge all necessary
erection.

All parts are to be carefully handled and
cessive hammering which would injure or distort
be resorted to.

Truss spans shall be erected on blocking placed
the proper camber, and the blocking shall be
until all truss connections are completely riveted

Bearing surfaces shall be cleaned before being
rollers and sliding shoes shall be both cleaned and
nections shall be accurately and securely fitted
driven. Holes which do not match shall be reamed.
distort the metal or gouging shall not be permitted
shall be placed in at least every third hole.

P. 163. *Correction of Errors of Connections**

It is probable that there will be some misfits in the connections of the steel work, of the machinery, of the machinery to the steel work, and of the timber to the steel work; and the Erecting Contractor shall be required to make all necessary adjustments and corrections in all parts to insure their proper connection. A usual amount of drifting, drilling, and correcting bad connections, and of scraping, lining, and preparing [illegible] expected, and is to be done by the Erecting Contractor without additional payment. Whenever, in the opinion of the Engineers, there is found to be an unusual and unreasonable amount of correction of shop errors, or correction of manufactured articles, the Erecting Contractor shall be paid for such as "Unclassified Work" under this contract; provided, however, that when the Erecting Contractor encounters cases wherein an extra payment seems properly due, he shall call the attention of the Engineers thereto, and if they decide that such is the case, they will give a written order, and the Erecting Contractor shall perform the work and shall present receipted detailed bills and vouchers for all expenses incurred, as provided under the "Unclassified Work" clause. No claims for extras due on such work will be considered at all, unless a definite written order is given therefor by the Engineers before the said extra work is started. If the Engineers decide in any such cases brought to their attention that extra payment is not proper, the Erecting Contractor shall proceed to perform the work, but no extra payments will be made and no claims therefor will be considered. All extra payments allowed the Erecting Contractor for correcting shop errors shall be paid by the Purchaser and deducted from the compensation of the Contractor for the manufacture and delivery of the metal work and machinery.

P. 164. *Falsework for Carrying Trains*

The Contractor for Erection must provide falsework of ample strength and rigidity to carry safely the trains of the Purchaser; and the plans for same must receive the written approval of the Engineers before the materials for the said falsework are ordered.

P. 165. *Erection Barges*

Whenever any spans are to be floated into position, the Contractor is to prepare complete plans for the necessary barges and falsework; and [illegible] must be submitted to the Engineers and receive their approval before [illegible] used, as must also the general scheme of doing such flotation.

P. 166. *Cement*

[illegible] cement used on the work must be Portland cement of the very [illegible] obtainable, equal in every respect to the best brands of

---

* [illegible] to be omitted when the Manufacturer does the erection.

[illegible]

[illegible] cement shall be ground so
[illegible] will pass a
[illegible] square inch, and so that at least
[illegible] sieve of forty thousand

When moulded neat into briquettes
until set, in air and the remainder of
it shall develop a tensile strength of at
five (175) pounds per square inch. When
after exposure of one (1) day in air and six
a tensile strength of at least five hundred
and after exposure of one (1) day in air
water, it shall develop a tensile strength
pounds per square inch. It shall be an
must develop its strength gradually, and

When moulded neat into pats with thin
or not to set in either air or water, the said
checking. The cement shall withstand
of the American Society for Testing Materials
the pats in any convenient way in an
water, in a loosely closed vessel for five (5)
shall remain firm and hard, and shall show no
cracking, or disintegrating.

The cement, when mixed neat with about
of water to form a stiff paste, shall after thirty
perceptibly by the end of a wire one-twelfth
loaded to weigh one-quarter (¼) of a pound.
similarly with a wire one-twenty-fourth ($\frac{1}{24}$) of
loaded so as to weigh one (1) pound, shall not
hours, unless the Engineers permit the use of
special purpose, in which case this time limit may
one (1) hour, but no lower.

Briquettes mixed in proportion, by weight, of
three (3) parts of sand, and kept one (1) day
time in water, shall show a tensile strength of at
pounds per square inch after seven (7) days, and
seventy-five (275) pounds per square inch after

In any case the cement adopted must first be

The Contractor shall provide a suitable building
in which the same must be placed before being
shall be notified of the receipt of cement for testing

before it is required for use, and the Inspector may take a sample from each package for the said testing. The Engineers will insist that no cement shall be used that has not been subjected to their twenty-eight (28) day test, and the Contractor must understand at the outset that this requirement will be insisted upon, even if the progress of the work be delayed thereby.

Any cement that has caked so as, in the opinion of the Engineers, to be injured shall be rejected; and it shall be removed by the Contractor from the neighborhood of the site in order to avoid all possibility of its being employed on the work.

P. 167. *Sand*

Sand shall be defined as particles of hard, clean stone which will pass a sieve having holes one-quarter (¼) inch square, and not less than fifty (50) per cent of which shall be retained upon a sieve having holes twenty-two thousandths (0.022) of an inch square, or what is commonly called a No. 30 sieve. It must be free from clay, silt, chips, and all other impurities, and must be reasonably sharp. In all cases the Engineers shall decide as to whether any sand offered by the Contractor shall be used on the work. If it be not satisfactorily clean, sand may be used if it is first washed or otherwise cleaned to satisfactory condition.

P. 168. *Broken Stone or Gravel*

Where not otherwise specified, either broken stone or clean, hard gravel of qualities satisfactory to the Engineers may be used in making concrete. The broken stone shall consist of pieces of hard and durable rock, such as trap, limestone, granite, or conglomerate, which shall be free from dust, clay, loam, or other material in such amounts as would, in the opinion of the Engineers, impair the strength of the concrete. The stone shall be crusher-run up to the sizes specified, with all material that will pass a one-quarter (¼) inch screen removed.

The gravel shall be composed of clean, hard pebbles screened to the specified sizes (crushed where necessary), free from clay, loam, or other material in such amounts that would, in the opinion of the Engineers, impair the concrete. Material that will pass a one-quarter (¼) inch screen must be taken out.

If they be not satisfactorily clean, materials may be used, provided they are washed or otherwise cleansed to satisfactory condition. Stone or gravel shall be stored on board platforms, and must not be shoveled up from the ground.

P. 169. *Concrete*

Broken stone shall, preferably, be employed in making concrete, but wherever gravel of a character satisfactory to the Engineers is available,

[illegible] of voids being [illegible] cement used shall be at least [illegible] of the voids in the mixture of sand [illegible] actual experiments and not by theoretical [illegible] shall there be used less than the following [illegible] yard of finished concrete:

For aggregates in which all the [illegible] before mixing, four hundred and twenty

For aggregates in which a natural mixture from the pit and modified by the addition of [illegible] and sixty (460) pounds.

For aggregates composed of a natural used without modification, five hundred

In large masses of concrete one-man vided that they first be cleaned and wetted, that they be not placed any nearer than six or to the exterior of the construction.

As previously specified, suitable forms must be provided to give the concrete finish shown on the drawings, all exposed as to produce a neat finish and in order to

The proportions for ordinary broken-stone

1 part of Portland cement,
3 parts of clean, coarse, sharp sand,
5 parts of broken stone, to pass a two
ring.

Those for reinforced concrete shall be as follows:

1 part of Portland cement,
2 parts of clean, coarse, sharp sand,
4 parts of broken stone, to pass a one and
iron ring.

Those for special concrete shall be as follows:

1 part of Portland cement,
2 parts of clean, coarse, sharp sand,
3 parts of broken stone, to pass a three-quarter

The latter proportions are to be used also for be placed under water before setting.

The amounts of all ingredients are to be determined the measurements are to be made loose. One barrel 380 pounds net, shall be considered to measure standard size bag of cement shall be considered foot. The sand and the broken stone or gravel measured by delivering to wheelbarrows or to

compartments of known volume. The method of measuring the ingredients of the concrete and the quantity of water used must be subject to the approval of the Engineers.

All surfaces of concrete constructions that are to be exposed to view are to be covered with an inch and a half (1½) shell of Portland cement mortar mixed in the proportion of one (1) part of cement to two (2) parts of sand and carried up simultaneously with the concrete.

The *modus operandi* of the construction of this shell shall be as follows, unless the Engineers give the Contractor written permission to employ some other method:

Steel plates one-quarter (¼) inch thick by twelve (12) inches wide and from four (4) to five (5) feet long are to be placed all around the construction at a distance of one and a half (1½) inches from the forms, and are to be blocked out from the latter every twelve (12) inches by small pieces of wood, the ends of the plates lapping slightly. Then the concrete is to be put inside the box thus formed to a depth not exceeding ten (10) inches and tamped thoroughly. Meanwhile the mortar is to be placed between the steel plates and the wooden form to a depth of about eleven (11) inches and tamped down, the wooden plugs being withdrawn gradually as the tamping proceeds. As soon as the exterior space is thus filled and before either the concrete or the mortar has had time to set, the steel plates are to be withdrawn by means of hooks inserted in holes placed near the upper edge for this purpose; then the mortar is to be rammed again so as to fill the voids left by withdrawing the plates.

If any bidder deem that this method of ensuring a smooth exterior is materially more expensive than that of omitting the outside mortar and the plates and, instead, of spading back carefully all the stones from the face, as is often done, he may state in his tender the difference in the price per cubic yard of concrete that the adoption of the latter method would cause; and due consideration will be given to this difference in awarding the contract. Such a bidder, however, is hereby warned that in no case will a rough exterior be accepted; nor will smoothing off with mortar afterward be permitted without special written permission from the Engineers.

All concrete is to be mixed by machinery, unless the Engineers permit otherwise. Batch mixers will be given preference over continuous mixers; and the latter will not be allowed on the work without special written permission from the Engineers. Whatever type or types of mixer be employed, the same must first receive the approval of the Engineers, and [illegible] method of supplying the materials to the machine must also meet their approval, as must also the quantity and quality of the water which must be free from oil, acids, strong alkalies, and vegetable [illegible] The machine shall be operated long enough after the last in[illegible] deposited in it to mix and to incorporate thoroughly all ingre[illegible] satisfaction of the Engineers.

[illegible]

[illegible] ground entirely, and until the
broken stone be used with gravel
the wet mass during the mixing.

Concrete shall be made with at least
light tamping will be required to
of the stone; but the use of an excess
mediately after the mixing is finished
place in such a manner that there shall
ingredients. It shall be rammed, tamped,
thoroughly in layers not exceeding twelve
otherwise agitated by suitable tools so as to
pact concrete of maximum density; and so
and so that the concrete will present a smooth
surface without exposed stones, when the forms
the exterior of the mass be mortar alone or
receive its initial set before being placed, it
immediately from the site of the work. Concrete
in deep, narrow walls shall be placed through a

Should, during construction, any surfaces of
harden or dry before the other concrete is placed
swept perfectly clean with brooms, then wetted
water and covered with a thin layer of one-to-one
a perfect contact between the old and the new
that the entire mass of concrete will be truly mono
of such dry surfaces, however, shall always be pre
and in all cases the placing of concrete shall be stop
as the Engineers may direct.

If it prove necessary to place concrete during
Contractor shall take all such precautions as the
to prevent it from being frozen.

All concrete shall be kept damp until thoroughly
or the forms containing it twice a day.

If, notwithstanding extreme care in the construction
placing and ramming of concrete, any imperfection
exposed surfaces when the forms are removed,
shall either be rubbed smooth or be floated with
one (1) part of Portland cement and two (2) parts
of the method to adopt being left to the Engineers

All concrete deposited under water shall,

means of a water-tight trémie, but buckets which open beneath and which are tripped by contact with the bottom may be used, if the Engineers approve. Buckets tripped by a line operated from above shall not be employed.

P. 170. *Continuity of Operation in Placing Concrete*

Whenever the Engineers shall so direct, the Contractor shall so conduct his work that the placing of concrete for any integral part of the structure shall be continuous and without any interruption whatsoever from start to finish. The Contractor shall not begin to place concrete for any integral portion of the construction until he shall have on the site of the work adequate materials, which have been inspected and accepted, to construct the said portion of the work without interruption.

P. 171. *Granitoid*

Wherever the plans call therefor, the tops of piers, pedestals, and abutments shall be finished off with granitoid of the following proportions:

One (1) part of Portland cement; two (2) parts of clean, coarse granite sand, or fine granite screenings; and three (3) parts of granite chips broken so small as to pass a one-half (½) inch iron ring. The top of this granitoid is to be brought to an exact level and finished with a floated surface. The thickness of the granitoid is to be as shown on the plans.

P. 172. *Wooden Piles and Pile Driving*

All piles are to be cut from live, straight, sound timber of a quality acceptable to the Engineers. They must be free from cracks, wind-shakes, and all serious defects; and they must be so straight that a right line joining the centres of ends of pile shall show that the said pile is at no point over one-third (⅓) of its diameter at such point out of straight line. They must show a gradual, even taper from end to end. The ends must be cut square; all bark must be taken off; and the branches and knots must be trimmed smooth, finishing the piles in a workmanlike manner. Unless otherwise specified, they must not be less than nine (9) inches in diameter at the top, and not less than twelve (12) inches nor more than sixteen (16) inches in diameter at the butt. They must be spaced accurately as per plans, and must be driven vertically or to correct batter and to the satisfaction of the Engineers, and, when required, they shall be cut off to exact level. All piling not conforming to these specifications will be rejected.

The Contractor shall provide a suitable and efficient pile-driver for driving the piles to the required depth without splitting them; and he must furnish, if the Engineers deem them necessary, rings and shoes for any or all piles.

Whenever the Engineers
of water-jets; and the
the Engineers. Two jet-pipes
invariably be used, because a single
travel toward the side where the jet
insist that at the outset of his
an ample volume of flow and an ample
piles; and the Engineers' judgment in

P. 173. *Concrete*

Concrete piles that are to be
be properly reinforced, as shown on the
to ensure that the reinforcing metal is
rect position. The piles are to be allowed
as the Engineers deem requisite. Any
injured in handling or before driving shall
concrete piles of this general type are to
viously specified for wooden piles, the use of
being mainly confined to static loading.
by hammering, the Engineers will reject it,
it to be withdrawn and removed from the

If the concrete piles are to be
manufacture must receive the approval of
be at liberty at any time to withdraw or dig
how satisfactorily the manufacturing has
of the method to the locality. If this test
method, the Engineers shall have the privilege
some other.

P. 174. *Position of Piers, Pedestals,*

All piers, pedestals, and abutments, when
position and to exact elevation, and all
located with the greatest exactness in respect
and elevation. The Contractor must provide
cables, frames, and forms that may be required

In sinking caissons by either the
process, in order that the pier-shafts may be
work of the latter shall not be begun until
final position, unless the Engineers give
trary. The Contractor shall provide a
for each pier in order to secure this result
overflow.

It must be distinctly understood by all
getting all piers, pedestals, and abutments

ntally and vertically, lies upon the Contractor and not upon the ngineers, and that if any error therein be found, the Contractor will have make at his own expense all the changes necessary to correct the error; else he must stand the entire expense involved in modifying the super- ructure to suit the faulty location of the substructure.

P. 175. *Depths of Foundations*

All cribs, footings, and caissons are to be sunk to the depths shown the Engineers' plans or to such other depths as the Engineers may deem ecessary as the work progresses. The data furnished to bidders by the gineers regarding depths of foundations or of bed-rock are to be consid- d as merely approximate; and bidders must assume the risk of having go a greater or less depth without altering in any way their schedule prices. If, however, the Engineers consider that the Contractor is y entitled to extra compensation on account of material variation the data furnished, such extra compensation will be allowed, but amount thereof shall be determined solely by the Engineers.

If, too, during the progress of the work the Engineers deem that fur- r investigations concerning the elevations of bed-rock or quality of terials for foundations are necessary, the Contractor shall make under direction of the Engineers, all the borings, tests of bearing capacity soil, or other similar investigations which the said Engineers may con- r to be requisite; and such work shall be treated as herein provided "Unclassified Work."

P. 176. *Caissons Sunk by the Pneumatic Process*

The construction of all caissons and cribs shall be in accordance with accompanying detail plans; and the Contractor's working drawings all be made to conform thereto. The said working drawings must be roved by the Engineers before work on the caissons is started.

In case of all-steel caissons, the Contractor in making the working wings shall adhere strictly to the Engineers' details; and in case of caissons the following directions must be observed:

First. All timbers are to be of the full length or width of the caisson er this is practicable.

Second. The cutting edges are to be shod with steel, unless specifi- indicated to the contrary on the drawings.

Drift-bolts are to be spaced not to exceed four (4) feet along k, and preferably about three (3) feet.

All framing of timber is to be done in a substantial manner the crib and caisson will hold their shapes in case that it be found force the cutting edges through logs or masses of large boulders.

Cribs and caissons are to be made water-tight by calking.

er-dams are to be used above the cribs in order that the

[illegible] of cribs and caissons [illegible]

P. 177. Caissons [illegible]

The construction of these caissons
ance with the detail plans. The Contractor
ing drawings for all such caissons, cribs,
same to the Engineers for their approval,
If it be intended to pump the water out of
made water-tight by calking the joints
sealed by the concrete; and this calking
of the Engineers. In case of all-steel construction
ing the working drawings shall adhere
and in the case of timber construction the
observed:

First. All timbers are to be of the full
whenever this is practicable.

Second. The cutting edges are to be shod
cally indicated to the contrary on the drawings.

Third. Drift-bolts are to be spaced not to
each stick, and preferably about three (3) feet.

Fourth. If the Engineers deem them necessary,
jecting water so as to loosen the material near
built into the timber and concrete as the
are to be spaced not to exceed eight (8) feet
to the walls of the working chamber, being
as to resist dislodgment during sinking. To
clogged with earth or gravel during the sinking,
be fitted with tight wooden plugs; and when
jetting purposes, the said plugs are to be driven
pipe for a ram.

Fifth. All framing of timber is to be done
so that the crib and caisson will hold their shapes
necessary to force the cutting edges through logs or

Sixth. Cribs and caissons are to be made

Removable cofferdams are to be used above
lower portions of the pier-shafts can be built in
for same must in all cases be removed before
No direct payment will be allowed for these
must be covered by the prices for concrete or
for mass of cribs and caissons below water.

P. 178. *Cofferdam Work*

In all cofferdam excavation, the designing of the cofferdams will be left to the Contractor, who will be held responsible for the ultimate completion of the piers, pedestals, or abutments for which the said cofferdams are used; but the designs must be approved by the Engineers before any of the work of construction is started. The cofferdams shall be so designed and built as to permit of all the water being pumped therefrom, in order that the footings may be laid in the dry, provided that this be practicable. If, however, in the opinion of the Engineers, it be impracticable, the construction shall be carried out by placing the concrete under water by means of a trémie or other special apparatus for the purpose that is approved by the Engineers. In this case specially rich concrete of small broken stone, as herein specified, shall be used. No direct payment will be made for cofferdam materials, as the cost thereof must be covered by the prices for excavation or materials in place. All timber and other cofferdam materials above the level of the ground or above that of extreme low water is to be removed by the Contractor from around the piers, pedestals, and abutments before his work will be considered completed; and no direct payment will be allowed for such removal, its cost being covered by the prices for the excavation or for the materials in place.

P. 179. *Maintaining Correct Form of Steel Shells*

In riveting up and sinking steel shells the greatest care is to be taken to keep them true to form; and no off-setting or divergence at joints will be permitted, unless so shown on the drawings. In many cases it will be necessary to bolt timbers to the shell temporarily, consequently the Contractor will be required to provide the necessary angle lugs therefor. As the onus of getting the shell down in proper shape is on the Contractor, the designing of the stiffening is to be done by him; notwithstanding which he must submit the design to the Engineers for approval before work is begun. All stiffening timbers must be removed before the concrete is put in, and, wherever necessary, before the piles are driven.

P. 180. *Excavation*

For caissons sunk by the open-dredging or the pneumatic process, no allowance will be made for the cost of excavation, this expense being covered by the price for mass of crib and caisson, or other materials, in place; nor where cofferdams are employed or where pits are dug will the excavation be paid for, unless this be specifically so stated in the contract. In computing the volume of excavation to be paid for in any pit, the sides of the latter are to be assumed as vertical, and no area will be allowed greater than that of a rectangle having each side longer by two (2) feet

than the corresponding side of the base of footing of the pier, pedestal, or abutment. No payment will be made for timber used in shoring, siding, or sheeting, nor for pumping nor bailing, as the cost thereof must be covered by the prices allowed for excavation or for materials in place.

Excavations for all constructions are to be carried to such depths as the Engineers may direct; and if, in their opinion, the foundation require any special preparation, it shall be given to it by the Contractor, the work involved thereby being paid for as "Unclassified Work," if the Engineers deem that it should be so considered.

Where bedrock is reached, the caisson, base, or footing, as the case may be, whenever practicable by ordinary methods, must be sunk into it one foot or as much more as the Engineers may consider necessary to obtain an even and proper bearing and a satisfactory anchorage against slipping. If the Engineers deem that the cost of such sinking into bedrock is unusual or excessive, they will allow additional payment therefor, as per the "Unclassified Work" clause of these specifications; but the amount of such payment shall be determined solely by the Engineers.

P. 181. *Encountering Obstacles*

Bidders must assume the risk of encountering logs, boulders, and other obstacles under the surface of the ground at the sites of the piers and abutments, and the Contractor must provide himself with all the necessary tackle and apparatus for handling the same. There will be no extra price allowed because of the difficulty experienced in sinking or driving through or in removing the said obstacles.

P. 182. *Pile Foundations*

The bases of piers, pedestals, and abutments which are to rest on piles shall be constructed by excavating within and sinking cribs, as indicated on the plans, to the required depth (preferably before the piles have been driven, but afterward, if the Engineers approve of that procedure). If the piles are driven after the crib is sunk, the earth which they force up into the crib shall invariably be removed; then the concrete shall be deposited in the dry, if practicable; otherwise through a trémie or by means of a single-line bottom-dumping bucket till the crib is filled uniformly to an elevation about two (2) feet below that at which the piles are to be cut off. If it be deposited in the dry, the concrete shall be thoroughly tamped or tramped with rubber boots in layers about one (1) foot deep. If it be deposited under water, it shall be mixed in the proportions hereinbefore specified for concrete deposited under water, and the crib shall be filled evenly over its area. As soon as the concrete has hardened adequately, the water shall be pumped out, the pile heads cut squarely off at the required elevations, and the remainder of the base built in the dry. The cribs shall be adequately caulked and braced to

the outside water pressure when they are pumped out, and shall be surrounded by cofferdams of adequate strength and height tect the construction from the highest water, and to carry whatever is required to sink the crib. The construction of the cribs shall accordance with the Engineers' general detail plans, but the design of the temporary stiffening shall be left to the Contractor. The Con-tor must prepare complete working drawings for all cribs, and must mit the same to the Engineers for their approval before work thereon tarted. All timbers are to be of the full length or width of the crib never this is practicable. Drift-bolts seven-eighths (7/8) of an inch diameter by twenty-two (22) inches long are to be spaced not to ex- four (4) feet along each stick, and preferably about three (3) feet. framing of the timber is to be done in a substantial manner so that crib will hold its shape in case that it be found necessary to force cutting edges through obstacles.

ould the Contractor so elect, he will be permitted to use sheet piles cofferdam construction, but in such cases the concrete bases of the s must be made of the same gross size as that shown on the drawings, the outside of the crib timbers.

The length and penetration of the foundation piles are to be deter- ed by the Engineers. They will be paid for by the lineal foot of pile ting below the crib-base; and a proper allowance will be made for actual cost of the cut-off ends.

P. 183. *Brick Piers*

The bricks must be sound, hard-burned, vitrified, and acceptable to Engineers. They must be wetted thoroughly before being laid, and mortar therefor shall be the same as that specified for stone masonry, joints being not less than one-quarter (1/4) of an inch nor more than half (1/2) of an inch thick, and the average not exceeding three-eighths of an inch. All brickwork shall be laid in Flemish bond, *i. e.*, alter-headers and stretchers with consecutive courses breaking joint. All shall be finished properly as the work progresses. The piers may of solid brickwork, or may consist of a brick shell backed with [illegible] None but expert bricklayers shall be employed to lay the [illegible] and all details of the work shall accord with the most approved [illegible] and must be to the satisfaction of the engineers.

P. 184. *Masonry in General*

masonry piers, pedestals, and abutments shall be built of either [illegible] second-class masonry, no third-class masonry or round-stone [illegible] being permitted. The shells alone of first-class construc- [illegible] masonry, the backing being invariably of Portland cement [illegible] before specified for interior work. The stone employed

[illegible]

P. 186. First

1. All first-class masonry shall be
suspicion, and must be laid in Portland
of cement and sand hereinafter specified
that the bearing beds shall be parallel to
be prepared by dressing and hammering
walls, as tooling and hammering will not
are in place. They are to be laid to a
in a full bed of mortar, without the
shelving projections will be allowed to
either side. The stone and work are to be
would interfere with the adhesion of the
sprinkled with water before being placed in
ing stones in mortar their beds are to be so
down they shall rest close and full on the mortar
care must be used not to injure the joints of
case a stone is moved after being set, and the
be taken out, the mortar must be cleaned
then the stone must be reset.

Wherever the Engineers shall so require,
two steel dowels each, one and a quarter (1¼)
through them and into the stones below. The
be drilled through such stones before they are
walls, and after the stones are in place the holes
into the under stones at least six (6) inches.
be set in, and the holes shall be filled with
Clamps binding the several stones of a course
when required by the Engineers. In such cases
into the stones which they fasten together

The face stones must be accurately squared,
their beds and builds; and the joints must be
(12) inches from the face. Face stones are to be
laid, of not more than three-quarters (¾) of an
(½) inch. The courses shall be not less than
ness, decreasing from bottom to top of wall;
The face stones shall break joints at least twel

[illegible] only the stones forming the [illegible] [illegible] to a uniform surface. The edges of [illegible] pitched true and full to line, and on the corners of all [illegible] draft of one and a half (1½) inches must be carried up from [illegible] to the under side of the coping. No projection of more than three inches from the edge of face stones shall be allowed. No stone with a ow face shall be permitted in the work.

Each stretcher shall have at least twenty-four (24) inches width of bed all courses of from fifteen (15) to twenty (20) inches rise, and for all cker courses at least two inches more bed than rise. The stretchers shall e an average length of at least three and one-half (3½) feet, no stretcher ng less than three (3) feet in length. Each header shall have a width t less than eighteen (18) inches, and shall hold back into the heart e wall the size that it shows on the face. The headers shall occupy ast one-fifth (⅕) of the whole face of the wall, and shall be, as nearly cticable, distributed evenly over it and so placed that the headers ch course shall divide equally, or nearly so, the spaces between the ers in the course directly below. No header shall be less than three a half (3½) feet long.

The tops of all piers shall be covered with copings, as shown on the ns. All coping stones shall be neatly bush-hammer dressed on the op, and underside of projection; and they shall be set well and ly on the walls, brought to one-quarter (¼) inch joints, and doweled, dowels being well secured in and to the coping with grout. No coping shall be less than nine (9) square feet in plan.

P. 186. *Second-Class Masonry*

Second-class masonry shall consist of broken range rubble of superior ity, laid with horizontal beds and vertical joints on all exposed parts, no stone less than eight (8) inches in thickness or eighteen (18) inches idth. In no case shall the bed of a stone be less than two (2) inches than its build. The stones must decrease in thickness from bottom of wall, and must be bonded and leveled as well as can be done hammer dressing. No mortar joints shall exceed one (1) inch ness. All corners shall have hammer-dressed beds and joints; and ers and batter lines shall be run with an inch and a half (1½) draft. At least one-fifth (⅕) of the stones in the face must be distributed evenly throughout the surface. All stones must be their natural beds. The backing shall be, preferably, of concrete for first class masonry construction, but solid stone work permitted, provided that sufficient mortar be used to fill all that no two stones approach each other nearer than one-half

[illegible]

P. 18[illegible]. Mortar [illegible]

This mortar shall be composed of and one-half (1½) parts of clean, being by volume and made loose. thoroughly dry, and after sufficient plastic, it shall be mixed and worked sistency throughout. Mortar that has take an initial set shall not be employed

P. 188. *Pointing*

All masonry, both first and second-class, the joints solid. The surface of the wall joints are to be freed from all loose mortar proper ramming tools. All joints must be Mortar used in pointing must be composed cement and one part of sand, measurements loose.

P. 189. *Arch Culverts*

All arch culverts are to be built of masonry, according to the preceding requirements and abutments, excepting only that in ring shall be of first-class masonry.

P. 190. *Laying Masonry during Freezing*

If it prove necessary to lay masonry during precautions, satisfactory to the Engineers, shall mortar from freezing.

P. 191. *Back-Filling*

As soon as the masonry or concrete work space around each shore pier, pedestal, and abutment earth, preferably clay, thoroughly dampened, and not exceeding six (6) inches in thickness. There ment for this back-filling, as its cost is to be excavation or that of masonry.

In case the boulders and gravel, or other site be excavated before constructing the base such completed pier shall be refilled to the original bed to the satisfaction of the Engineers; and the Contractor for such back-filling; but any the said pier for protection above the said natural bed shall be paid for as riprap, if there be a unit

otherwise as "Unclassified Work." Should, however, the Engineers em that the excavated materials are unfit for back-filling and require e Contractor to use instead large stones or boulders, these are likewise be paid for as riprap.

If any material from an existing embankment is removed by the ntractor in order to put in a pier or abutment, it shall be replaced by m at his own expense under this specification for back-filling, and he shall ceive no payment therefor; but this clause shall not be interpreted as n any way obligating him to build at his own expense any more of the arthwork approaches.

P. 192. *Preparing and Placing Reinforcing Bars*

The reinforcement in the finished structure shall accurately conform size and position to the requirements of the plans. Before being placed the concrete, all reinforcement shall be free from loose rust, scale, or ating of any kind that would tend to reduce the bond between it and e concrete. All reinforcing bars shall be bent cold to the dimensions d forms shown on the drawings before they are placed in position. he bends shall be accurately made in a bending machine. All reinforc- g bars shall be placed and held during construction accurately in the tions shown for them on the accompanying drawings. They shall firmly bound and tied together by wire where they lap or cross, or all be fastened by clips or other devices where specially called for. ach piece must be held rigidly and positively in position so that there hall be no displacement during the depositing of the concrete. Adjust- ent of bars during the placing of concrete will not be permitted. Where essary, small blocks made of cement mortar may be used to support reinforcing rods at proper distances from the forms.

P. 193. *Earth Embankments*

Beyond the abutments at each end of the bridge there will be earth ments. These will be paid for per cubic yard in place above esent ground surface. The material used for the embankment is to y, sand, loam, gravel, or other earthy material free from pieces of , roots, or other foreign substances, and is to be placed in the em- ments in layers one foot in thickness, the surface at all times being about level. Dumping from the top of the embankment down the end-dumping will not be allowed. Slopes are to be formed even ght, correctly conforming to the slope stakes. The permissible and location of borrow pits contiguous to the embankments rmined by the Engineers, but in all cases the borrow pits are , forming drainage ditches. About ten (10) per cent the net lines of embankment shall be placed in order to allow

[illegible]

[illegible] shall be [illegible]

[illegible] and thereon must conform [illegible]

specifications, as must also the [illegible]

P. 195.

The Contractor shall furnish and

on the accompanying drawings. In

ship, and finish thereof, the general

shall govern throughout.

P. 196.

The Contractor shall furnish and

accompanying plans. The piles therefor

tions for wooden piles given herein, and

depths as the Engineers may direct. The

drawn together at the top, bolted, and

which is securely fastened with clips and

P. 197. *Bank Pro*

The Contractor shall furnish all the

satisfaction of the Engineers the bank

panying plans. All the materials and labor

the general requirements of these specifications.

V. 198. *Pile Dykes and Ma*

When the bank protection consists of pile

and detailed descriptive specification therefor

unusual bridge materials employed, such as

their qualities defined.

As an example, the following is copied from

some dyke-work that did good service during

Example

This dyke is to be composed of a main pile

with cross-dykes at intervals of about 400 feet

principally on an easy curve, starting at the foot

down to the line of the "Temporary Bridge."

[illegible]

of two rows of piles spaced six (6) feet centres [illegible] hown on the accompanying drawings, capped with 8″ × 10″ timbers flat running longitudinally, and braced with 6″ × 8″ timbers on [illegible] th transversely and diagonally as shown. The rear row of piles is to wattled, and a fifty (50) foot mat is to be built in front of, around and d the piles. Each cross-dyke is to consist of a single row of piles ed six (6) feet centres, wattled, and capped with 8″ × 10″ timbers.

In general, the piles of the main dyke are to be cut off about three d one-half (3½) feet above extreme low water mark, but as the said ke approaches the river bank at Avenue J the piles are to be gradually off higher up so that at the shore line they will be as high as the top the bank. The piles of the cross-dykes are to be cut off so that their will lie in a plane, their elevation at the main dyke being the same that of the piles of said main dyke, and the elevation of the piles at other end about that of the top of the river bank. All piles are to of white or burr oak, forty (40) feet long, from eight (8) to ten (10) hes in diameter at the tip and not less than fourteen (14) inches in meter at the butt. All piles must be driven as closely as practicable their proper position, and any piles which the Engineers may consider be too much out of line will have to be removed and re-driven.

All timber for caps and bracing is to be of white oak of the best quality, from wind-shakes, large knots, decayed wood, sap, or any defects that uld impair its strength or durability. Cap timbers are to be 8″ × 10″ d on flat and sized down to a uniform thickness. They are to be twelve) feet long with square butt joints, fitting tightly. The transverse braces to be 6″ × 8″ by seven (7) feet long, laid on flat and dapped two inches onto caps directly over the centres of the piles. The diagonal es are to be 6″ × 8″ by nine (9) feet long, laid on flat, dapped two inches onto caps, and pressing closely at ends against the transverse mbers. The daps on both the transverse and the diagonal timbers are all cases to be so cut as to give a driving fit against the caps.

All steel used in the work must conform to the Manufacturers' Stand- Specifications. The drift bolts connecting caps to piles are to be quarters (¾) of an inch in diameter and eighteen (18) inches long, into eleven-sixteenths (11/16) inch holes. There will be two drift per pile. Spikes for connecting bracing timbers to caps are to be eighths (⅝) of an inch square and twelve (12) inches long. There to be two (2) of them used at each end of each transverse or diagonal timber. These spikes are to be driven into one-half (½) inch holes.

wattling pieces are to be of good, sound, live willow, sycamore, wood, in lengths of either fourteen (14) or twenty-one (21) feet, diameters of three and one-half (3½) inches at the one-half (½) inch at the tip. The said wattling pieces are so as to touch each other, alternating large and small

ends and reducing the area of
end. The wattling is to extend
caps of the piles. All wattling is to be
the piles.

After the piles are driven, but before
woven mattress from twelve (12) to
(50) feet wide is to be manufactured
length of the main dyke, the rear edge
the centre line of the inner row of piles. All
none but good, live, bar-growth, freshly
The style of weaving shall be the same
upon the works of the United States Gov
be continuously woven, the edge being
vanized strand steel rope, with the selvage
with a woven roll. At intervals of six (6) feet,
verse cables $\frac{3}{8}$ inch in diameter shall be placed
tom of the mattress, and connected effectively
Vertical ties of $\frac{9}{32}$ inch wire rope at intervals of
top and bottom longitudinal and transverse
thoroughly tightened so that the said longitudinal
shall bear tightly and intimately on the top and

A grillage of willow, sycamore, or cottonwood
twelve (12) feet in length or four (4) inches
placed on top of the entire mattress work. They
than six (6) feet from centre to centre, and shall
the mattress work by $\frac{9}{32}$ inch wire rope. Anch
in the shape of native stone of an approved qual
portion of twenty (20) pounds per square foot
more stone near the exterior edge of the mattress
than on the remaining portions. The distribution
made to the approval of the Engineers. The
be from thirty (30) to one hundred and fifty (150)
up-stream end of the dyke the mattress is to be
with rock and attached from the selvage edge by
cables to dead-men in the bank in a manner to be
neers. All wire rope used in the work shall be
thoroughly galvanized. Workmanship throughout
men only being employed.

After the completion of the dyke or any por
piles thereof is to be anchored down (so as to
up by ice) with two seven (7) inch cast iron
a loop of nine-thirty-seconds ($\frac{9}{32}$) inch wire
river with a water-jet harpoon eighteen (18)
the mattress. Instead of fastening these cable
be attached to the caps. They must be twisted

on each of them, and must be securely fastened to either the cage or the piles.

P. 199. *Adherence to Specifications in Bidding*

All the work herein outlined is to be done in strict accordance with these specifications, the accompanying plans, and such instructions as may be given from time to time by the Engineers. Bidders are hereby warned that they will be held strictly to the spirit of the specifications, and that it will be bad policy for any one to bid with the expectation that concessions will be made after the contract is closed, in order that the work may be cheapened or expedited. On this account bidders are respectfully requested not to complicate their tenders by submitting alternative bids based upon proposed changes in either plans or specifications, because such alternative bids will not be considered.

V. 200. *Scope of Contract*

In this clause should be stated clearly in detail everything that the Contractors shall have to do and to furnish, and where and how they are to deliver all the materials. If any parts are to be excluded from the contract, this should be indicated; and the division of the work among the various Contractors should be made perfectly clear. In this clause should be mentioned, even if the same be stated elsewhere, who is to attend to the work of removing the existing structure, if there be one to be removed, and at whose expense.

This is a most important clause, and it should receive the fullest consideration, to the end that there shall not be the slightest doubt in any bidder's mind as to exactly what he is and what he is not to furnish or perform. Special mention should be made of anchor bolts which are to be embedded in the masonry at the time of its construction, so as to make it clear whether they are to be included or not, because in some instances they are furnished by the Contractor for the substructure and in others by the Contractor for the superstructure. If they are to be furnished by the Manufacturer of the superstructure, and if they are needed before the rest of the metal, this should be stated, and the required date or dates for delivery thereof should be given. This last instruction applies also to any metal for the substructure that is to be furnished by the Manufacturer, such, for instance, as buried girders for piers.

Under the next heading; "Approximate Quantities of Materials," will be found a list of items that may enter into the construction of any bridge. It will be useful in preparing this clause, because its perusal will prevent omission in the scope of the contract.

Example

to be done at present will be let under three contracts to

bidders.

[illegible]
[illegible] and attachments [illegible]
[illegible] as shown on the [illegible]
[illegible] in these specifications.

B. Contract for Furnishing of
[illegible] the furnishing f. o. b. cars
required for the superstructure of
1A, 4, and 5, omitting only the towers
to be lifted, the machinery on the
ropes, and the metal in counterweights.

C. Contract for Erecting of
as Simple Spans, as shown on drawings
receiving, checking, unloading promptly
work for the superstructure under Contract B,
responsible for all demurrage due to cars
the erecting, riveting, adjusting, cleaning,
ing all of said metalwork; and the furnishing
materials and building the entire superstructure
traffic as a fixed span bridge, as shown on the
1A, 4, and 5 and described in these specifications.

At a later time two further contracts will
fications, as follows:

D. Contract for Furnishing of all
Machinery required to make one span operative
on drawings 1*A*, 6, 7, 9, and 10, and Sheets
and *M*7: This contract shall include the furnishing
B. C., of all superstructure metalwork not furnished
all the necessary machinery, apparatus, motors,

E. Contract for Erecting of Superstructure
forming all work necessary to convert the bridge
include the receiving, checking, promptly unloading
the metal work required to make one span operative
shown on drawing 1*A*), the extra members on the
the machinery, apparatus, and electrical equipment
and towers, and the metal in counterweights;
demurrage due to cars not being promptly unloaded
justing, riveting, cleaning, furnishing the paint,
metal work; furnishing and applying oil for
guides; furnishing and applying dressing for
terials and building complete the machinery house
rials, except the enclosed steel, and building
terweights; performing all work necessary to
operating condition; and the furnishing of the

[illegible] the end of that period properly [illegible]
in perfect order.

V. 201. *Approximate Quantities of Materials*

In this clause should be given, as accurately as practicable or convenient, a list of all the different materials required for the entire structure or structures and the quantity thereof for each kind. The grouping of the metal items should be arranged according to the pound prices of the different kinds of finished metalwork. It is well not to make too many groups, but care should be taken that the items included in each group be of approximately the same value per pound. If the division be simply ordinary structural steel and machinery metal, as is often the case, care should be taken to indicate clearly just where one class of metalwork ends and the other begins.

The following is a list of nearly every kind of material and work entering into the construction of the superstructure of a steel bridge:

1. Ordinary structural steel. (Can be divided into several items if desired.)
2. Reinforcing bars.
3. Machinery metal (this may all be grouped together or may be separated into component parts).
4. Nickel steel or other special alloy of steel.
5. Pavement for main roadway.
6. Concrete or reinforced concrete base for main roadway.
7. Concrete or reinforced concrete slab for sidewalks.
8. Untreated timber.
9. Treated timber.
10. Steel rails and their attachments (including special rail details and bonding).
11. Electric motors and other electric apparatus.
12. Gasoline engines.

Electric or other lighting.

Signals and switches for tracks.

Interlocking apparatus.

Wire ropes and their attachments.

Wire rope dressing.

Concrete or other materials in counterweights.

Machinery houses.

Wooden trestle approaches.

Draw protection.

Pile dykes.

[illegible] work.

Removal of old spans.

25. Removal of shafts of piers
26. Removal of bases of old piers
27. Water pipes and apparatus for fire
28. Hand-rails.
29. Shelter houses for pedestrians and
30. Gates.
31. Smoke protectors.
32. Downspouts for water.
33. Waterproofing of floors and roofs.
34. Earth embankments for approaches.
35. Macadam on embankments.
36. Ties on embankments.
37. Curbing on embankments.
38. Trolley line.
39. Falsework to carry trains or other traffic.
40. Temporary bridge or trestle.
41. Untreated piles.
42. Treated piles.
43. Riprap.

The following is a list of nearly every kind of
enter into the construction of the substructure of

1. Ordinary structural steel.
2. Reinforcing bars.
3. Concrete in shafts of piers, pedestals, and
4. First-class masonry in shafts of piers, pede
5. Second-class masonry in shafts of piers, pe
6. Untreated timber in cribs and caissons and
   piers, pedestals, and abutments.
7. Concrete in cribs and caissons and in bases
   abutments.

(N. B.) Items 6 and 7 are frequently combine

8. Granitoid.
9. Untreated timber piles in and below bases
   abutments.
10. Treated timber piles in and below bases
    abutments.
11. Reinforced concrete piles in and below
    and abutments.
12. Untreated timber in pier protection.
13. Treated timber in pier protection.
14. Untreated piles in pier protection.
15. Treated piles in pier protection.
16. Pile dykes.
17. Mattress work.

18. Shafts of old piers, pedestals, and abutments to be removed.
19. Bases of old piers, pedestals, and abutments to be removed.
20. Old spans to be removed.
21. Falsework to carry trains or other traffic.
22. Temporary bridge or trestle.
23. Earth in fills back of abutments and in embankments.
24. Macadam on earth embankments.
25. Paving on earth embankments, including concrete base.
26. Sidewalk floors on earth embankments.
27. Hand-rails on earth embankments.
28. Ties on embankments.
29. Curbing on approaches.
30. Steel rails and their attachments.
31. Earth excavation.
32. Rock excavation.
33. Riprap.
34. Removal and rebuilding of sewers and other pipes and conduits.

The following is a list of nearly every kind of material and labor that enter into the construction of reinforced concrete bridges:

1. Ordinary structural steel.
2. Reinforcing bars.
3. Pavement for main roadway.
4. Concrete or reinforced concrete base for main roadway.
5. Concrete or reinforced concrete slab for sidewalks.
6. Steel rails and their attachments (including special rail details and bonding).
7. Electric or other lighting.
8. Signals and switches for tracks.
9. Interlocking apparatus.
10. Pile dykes.
11. Mattress work.
12. Removal of old spans.
13. Removal of shafts of old piers, pedestals, and abutments.
14. Removal of bases of old piers, pedestals, and abutments.
15. Downspouts for water.
16. Earth embankments for approaches.
17. Macadam for earth embankments.
18. Ties in earth embankments.
19. Curbing on earth embankments.
20. Trolley line.
21. Falsework to carry trains or other traffic.
22. Temporary bridge or trestle.
23. Untreated piles.
24. Treated piles.

25. Reinforced concrete piles.
26. Riprap.
27. Concrete in hand-rails.
28. Concrete in floor slabs and fascias.
29. Concrete in cross-girders and cantilever brackets.
30. Concrete in main girders.
31. Concrete in cross-walls or spandrel columns of arch spans.
32. Concrete in arches.
33. Concrete in shafts and copings of columns, piers, pedestals, and abutments.
34. Concrete in bases of piers, pedestals, and abutments.
35. Concrete in cribs and caissons.
36. Granitoid.
37. Sand filler.
38. Untreated timber in cribs and caissons and in shells for bases of piers, pedestals, and abutments.
39. Earth excavation.
40. Rock excavation.
41. Removal and rebuilding of sewers and other pipes and conduits.

This clause should either begin or finish with a paragraph similar to the following:

The figures given herein are only approximate, and neither the Purchaser nor the Engineers shall be held responsible in any way for their correctness.

EXAMPLE

The following are the approximate quantities of materials in the superstructure. They are to be used in comparing tenders, and are only approximate. They are not to be considered in any way as binding upon the Province or the Engineers:

Superstructure (without Lifting Details)

Metal in trusses, etc.	447,000 lbs.
Timber	120 M. ft. B. M.

Substructure

Metal in cylinders and bracing	268,000 lbs.
Concrete in cylinders and bracing	831 cu. yds.
Concrete in abutments	507 cu. yds.
Earth in embankments	1,125 cu. yds.

Superstructure Lifting Details, Machinery, and Towers

Metal in span	21,000 lbs.
Metal in towers	85,400 lbs.

Machinery on span	15,000 lbs.
Sheaves and bearings on towers	7,300 lbs.
Ropes	3,500 lbs.
Timber in walkways	4 M. ft. B. M.
Metal in counterweight	7,400 lbs.
Concrete in counterweight	67 cu. yds.

V. 202. *Time of Completion*

The time or times of completion of the work should be distinctly stated so that there shall be no doubt whatsoever concerning the date at which any important division of the construction is to be finished. If the Purchaser is to furnish any of the materials to the Contractor, or if the latter's work in the field is dependent upon that of any other contractor, provision should be made in this clause for an extension of time in case of any delay caused by the non-delivery of such materials in due time or by the non-completion of the other contractor's work at the date or dates fixed; and the said extension of time should be limited to the actual time of delay, unless the said delay should run the Contractor into a season unfavorable to doing his field work, in which case an equitable extension should be arranged for.

EXAMPLE

If this contract includes the construction of the substructure only, the entire work shall be completed within six (6) months from the date of the contract.

If this contract includes the construction of the substructure and the erection of the steel work and machinery, and the furnishing and erecting of all other materials required for the complete bridge, the entire work shall be finished within eight (8) months from the date of the contract, unless in the opinion of the Engineers, the Contractor be delayed by the non-delivery of the steel work and machinery f.o.b. cars at Black River Station, Louisiana, within five (5) months from the date of the contract, in which event the time for completion of the entire work shall be extended the amount of time the Contractor is, in the opinion of the Engineers, delayed by the non-delivery of the steel and machinery within the time specified.

If this contract shall include the manufacture and delivery f.o.b. cars at Black River Station, Louisiana, of the steel, machinery, and accessories for the superstructure, the entire work shall be completed and delivered at Black River Station, Louisiana, within five (5) months from the date of contract.

If this contract include the furnishing of all materials for and constructing the complete superstructure, the entire work shall be finished ready for service within eight (8) months from the date of the contract,

unless, in the opinion of the
substructure to complete his work
erection of the superstructure, in
of the entire work shall be extended the
in the opinion of the Engineers, delayed by
within the time specified.

If this contract include the furnishing
struction of the entire structure, the
service, to the satisfaction of the
the date of this contract.

I. 203. *Rate of*

The Contractor shall commence work at
may direct, and shall conform to their
time in which the different parts of the
to the force required to complete the
fied. If, during the construction, it
Contractor is not making proper progress,
right, after giving the Contractor ten (10)
undertake himself, either by administration
other parties, the completion of the said
lected. Should the Purchaser's work cost less
would have been paid, the difference shall be
on the other hand, should it cost more, the
to the Contractor, and shall be taken out of
or out of the bond. Under these circumstances
the right to enter upon and take temporary
materials, and supplies of the said Contractor,
case that the percentage of earnings withheld
ficient to make good the deficit, the Purchaser
reimburse himself by the sale of the Contractor's
the said plant shall be returned to the Contractor
the work.

If, in the opinion of the Engineers, the shopwork
delayed or is about to be delayed because of
or because of the asserted inability of the
Purchaser shall have the right, after giving the
notice in writing, to purchase the required metal
deliver it to the shops, and to charge all costs
against the Contractor.

I. 204. *Liquidated Damages*

For each day (Sundays included) of delay
of the materials (or in completing the

[illegible] accordance with the terms of these specifications and of the said contract, the Purchaser shall withhold permanently from the Contractor's total compensation the sum of ....($.....). The amount thus withheld is not to be considered as a penalty, but as liquidated damages, fixed and agreed to in advance by the contracting parties.

On the other hand, if the Contractor complete the delivery of the said materials (or construction) covered in the contract, all in accordance with the terms of these specifications and of the said contract, before the said specified time, the Purchaser shall pay to the Contractor as a bonus for his diligence and as a just acknowledgment of the value to the Purchaser of the time thus saved the sum of..........($....) for each and every day (Sundays included) that the said delivery (or construction) is completed in advance of the specified limit.

If, in the opinion of the Engineers, the Contractor be delayed by circumstances that are absolutely beyond his control, the Engineers may grant him an extension of time for the completion of his contract, but the determination of the amount thereof is to be left entirely to the said Engineers. In such a case the liquidated damages and the bonus are to be computed from the extended date instead of the date originally specified for completion.

If, in *any case or for any cause whatsoever*, the Contractor fail to finish the delivery of the materials (or completion of construction) within the time [illegible] originally set in the specifications, the Contractor shall pay to the Purchaser for the Engineers a sum of money adequate to reimburse the [illegible] for all expenses of every kind incurred by them because of the delay thus involved. This reimbursement of expense to the Engineers is under no circumstances to be waived; but the proper amount is to be deducted from the Contractor's payments.

I. 205. *Bond*

The Contractor will be required to give to the Purchaser a surety-company bond, satisfactory to the Purchaser, in the sum of .... dollars ($......), for the faithful performance of the contract and the specifications and of all the terms and conditions therein contained, and for the prompt payment for all materials and labor used in the manufacture and erection of the structure (or structures), and to protect and save harmless the Purchaser because of injury to persons or property, caused [illegible] negligence, or claim of negligence, on the part of the Contractor, his [illegible], servants, or employees in doing the work or in connection therewith; also from violation, or claim of violation, of patent rights by the [illegible] and from all loss of or damage to the property of the Purchaser.

The bond shall be so drawn as to permit of changes being made in [illegible] specifications during the construction of the work, or of [illegible] time for its completion, without nullifying in any manner

[illegible]

[illegible] for work shall be made [illegible]

[illegible] the first day of the month [illegible]

value of the work done and the materials [illegible]

fifteen (15) days thereafter ninety (90) [illegible]

[illegible] less previous payments, shall be paid [illegible]

Upon the completion of the entire work [illegible]

upon the acceptance of the same in writing [illegible]

due the Contractor for the entire work shall [illegible]

in cash.

Before, however, the final payment is made [illegible] to the Purchaser satisfactory evidence that [illegible] demands of his employees, or of parties from [illegible] the construction of the work may have been [illegible] fully satisfied; and that the materials furnished [illegible] the structure are fully released from all such [illegible] If, too, during the progress of the work, it appears [illegible] bills for materials and labor are not being paid [illegible] the right to withhold from the Contractor's money [illegible] sum or sums to guarantee himself against all [illegible] other possible liens, and to apply the said sum [illegible] of such debts.

P. 207. *Unclassified W*

The Engineers shall have the right to require [illegible] work or supply materials of any class not provided [illegible] such to be known as "Unclassified Work." In case [illegible] are ordered, they shall be paid for on the basis of [illegible] tractor of the materials and applied labor, plus [illegible] profit, no indirect expense of any kind being incl[illegible] articles or products ready for installation are furn[illegible] instead of the constituent materials, the Contractor [illegible] profit ten (10) per cent on the cost to him of such [illegible] will be made for superintendence, insurance, or any [illegible] or for the use of tools or appliances. Satisfactory [illegible] quired from the Contractor for all expenses of uncl[illegible] ment for any such work will be allowed unless it [illegible] by the Engineers before execution.

P. 208. *Bidders' Plant and Evidence*

At the time of opening of bids any or all bid[illegible] give satisfactory evidence that they have had [illegible]

[illegible] or [illegible] of these [illegible] to perform other contracts may be rejected [illegible] bidder on substructure or erection of superstructure shall submit [illegible] tender a full statement of the equipment he has available for [illegible] work for which he tenders.

V. 200. Tenders

In this clause there should be listed all the materials given in the clause entitled "Approximate Quantities of Materials," and a space should be left blank for the schedule price to be written in. Either at the [illegible] of the list or in each item, it must be clearly stated whether the prices cover material delivered at site, material in place, erection only, or otherwise. Directions should be given as to how the tenders are to be prepared and presented, and the date set for opening the bids should be stated.

EXAMPLE

Bids will be received by the Chief Engineer of the Department of Public Works of the Province of British Columbia, at Victoria, B. C., up to noon of .... No bid will be considered which is received after that time.

Bids shall be made as follows:

First. For the substructure, as described in Paragraph A under Scope of Contract, tenders shall be made thus:

For metalwork in piers and bracing girders in place, and painting same, ... cents per pound.

For concrete in piers and bracing girders, ... dollars ($) per cubic yard.

For concrete in abutments, in place, ... dollars ($) per cubic yard.

For earth fill behind abutments, ... cents per cubic yard.

Second. Tenders for the furnishing of the superstructure metalwork according to Paragraph B under Scope of Contract, shall be made as follows:

For furnishing f.o.b. cars at Trail, B. C., all of the superstructure metalwork for the fixed spans, ... cents per pound.

Third. For erecting the metalwork and completing the superstructure of the fixed spans, according to Paragraph C under Scope of Contract:

For erecting the metalwork and furnishing and applying the field coat of paint, ... cents per pound of metalwork.

For furnishing and erecting in place the timber floor, including the [illegible] and fastenings for the timber, ... dollars ($) per M. B. M. of timber in place.

For furnishing the steel work, electrical equipment, and the

[illegible] shall tender as follows for [illegible]

a. For structural metalwork to be for that in counterweights, ...

b. For all machinery on the movable

c. For main sheaves, shafts, and bearings per pound.

d. For suspending and operating .... cents per pound.

e. For electric motor, electric controller switchboard, and appurtenances, ...

Fifth. Bidders for the erection of fixed span into a movable span, according to Contract, shall tender as follows:

a. For unloading and erecting the structural movable span, and that in the towers and in the furnishing and applying the field paint to the per pound.

b. For unloading and erecting the machinery for furnishing and applying the paint to the pound of machinery.

c. For unloading and erecting the sheaves, towers, and for furnishing and applying the cents per pound of metal.

d. For unloading and erecting the and attachments, and for furnishing and the same, ... cents per pound of metal.

e. For unloading and erecting the electrical nishing and putting in place all wiring and the appurtenances necessary to make the electrical adequate for the satisfactory operation of the bridge ($).

f. For furnishing all materials for and machinery house and walkways on the bridge ($).

g. For furnishing all the material for and counterweights, ... dollars ($)

V. 210. *Form of Proposal*

Occasionally it is necessary to have all tenders prepared by the Purchaser, in which case they should materials in a vertical line to the left of the page rows for filling in the schedule prices and the

In such cases there should be a clause similar

All proposals shall be made upon blanks furnished by ...., (or herewith enclosed, or accompanying these specifications).

P. 211. *Deposit Check and Forfeiture Thereof*

Each tender must be accompanied by a properly certified check for ....dollars ($......) (or for .... (......) per cent of the total amount of the said tender) made payable to .... The check of the successful bidder will be returned upon execution of contract and acceptance of bond. All other checks will be returned immediately upon execution of contract. Any bidder who refuses or fails within ten (10) days to enter into contract after it has been awarded to him will be declared irresponsible, and his check will be forfeited to the Purchaser. If any bidder neglect to deposit with his tender the required certified check, or if there be any irregularity in the check he deposits, or if the bank upon which his check is drawn be not solvent, his tender shall be rejected.

P. 212. *Integrity of Bid*

Each bid must be accompanied by an affidavit to the effect that the bid is genuine and not sham nor collusive, nor made in the interest nor on behalf of any person or corporation not named therein, that the bidder has not directly or indirectly induced or solicited any bidder to put in a sham bid or induced any other person or corporation to refrain from bidding, and that the bidder has not in any manner sought, by collusion, to secure to himself an advantage over other bidders. Any bid made without such affidavit, or in violation thereof, shall be absolutely void.

P. 213. *Withdrawal of Tender*

No tender can be withdrawn after it has been officially opened or after the date set in the specifications for opening it, unless it shall have been [illegible] unopened more than thirty (30) days after the said date set for opening.

P. 214. *Award of Contract*

As soon as possible after the award is made, a contract similar to that outlined on the accompanying form will be presented in duplicate to the successful bidder for his signature, after which both copies will be signed [illegible] the Purchaser, and one copy will be retained by each of the parties [illegible] the agreement.

Before any bidder is awarded the contract for the work, he must, [illegible] requested by the Purchaser, furnish satisfactory proof of his financial [illegible] ability to deliver the materials and carry on the construction, [illegible] by these specifications. Failure so to do will involve the [illegible] deposit check.

[illegible] the Contractor's [illegible]
[illegible] or subletting shall [illegible]
[illegible] transfer of contract [illegible]
[illegible] of any of his liabilities under [illegible]
[illegible] fail to perform the work [illegible]
[illegible] the Engineers may at their option [illegible]
[illegible]. Copies of all subcontracts that are [illegible]
[illegible] Engineers.

P. 216. *Rejection of* [illegible]

The Purchaser reserves the right to reject [illegible]

P. 217. *Return of Papers*

All papers submitted to bidders, excepting [illegible]
bidder, are to be returned to the Engineers [illegible]

I. 218. *Meaning of Terms*

Wherever in these specifications the term "[illegible]
it is understood to refer to .... [illegible]

Wherever in these specifications the term "[illegible]
is employed, it is understood to refer to .... [illegible]
authorized representatives. Wherever the term "In[illegible]
spectors" is used, it is understood to refer to the [illegible]
Engineers (Engineer).

Whenever in these specifications the term "this [illegible]
is employed, it is understood to refer to all the work [illegible]
tioned throughout these specifications or indicated on [illegible]
accompanying the same.

Whenever the term "Contractor" is employed, [illegible]
mean any person or corporation that may have [illegible]
with the Purchaser for this work or any portion thereof [illegible]
to Contractor applies equally to all Contractors [illegible]
unless there is specific limitation to the contrary.

(Place and Date) ....

CONTRACT

Between

Purchaser:

And

Contractor:

For

Dated .... at ....

(Engineers)

MEMORANDUM OF AGREEMENT, Made and signed this ....day of......................, at ...., by and between

the party of the first part, and sometimes termed in this agreement and in the specifications the "**Purchaser,**" and

the party of the second part, and sometimes termed in this agreement and in the specifications the "**Contractor.**"

WHEREAS.

WHEREAS, The **Contractor** has, under date of...................., made a satisfactory tender for

NOW THIS AGREEMENT WITNESSETH:

First. The **Contractor,** for and in consideration of certain payments to be made to him as hereinafter specified, hereby covenants and agrees to provide, at his own cost and expense, all labor, machinery, plant, tools, and appliances, and to

all in accordance with the **Plans** and **Specifications** hereunto annexed and made a part hereof, and will fully finish and complete the same by

but, if, in the opinion of the **Engineer**, the **Contractor** be delayed or prevented in the prosecution of the work by conditions absolutely beyond the control of the **Contractor**, additional time for completion of the contract will be allowed, and the amount of such additional time will be determined and fixed solely by the **Engineer**.

Second. The **Contractor** shall start the work of construction as soon as practicable after the signing of the contract, and shall carry on the work with adequate diligence to ensure its completion within the time specified.

Third. In consideration of the performance by the **Contractor** of his covenants and agreements, as herein set forth, the **Purchaser** hereby covenants and agrees to pay the **Contractor** as follows:

In case the **Engineer** require the **Contractor** to perform work or to supply materials of a class not included and covered in the above list of items nor, in the opinion of the **Engineer**, described or implied as included in the above list by the plans and specifications, such materials and work shall be paid for as provided in the clause for **Unclassified Work** in the attached specifications.

* No payments, either partial or final, are to be made for any material which is to be used for falsework or plant; but payment is to be made only for materials which are left permanently in the finished structure and form a part of it. The **Engineer**

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* This sentence may occasionally have to be modified or omitted.

may, at his discretion, allow temporary partial payments in advance of the permanent work as materials for plant and falsework are employed, but the **Contractor** shall have no right to demand such compensation.

Fourth. The schedule prices to be employed in making partial payments for all work as it progresses are to be determined by the **Engineer.**

Fifth. All material paid for by the **Purchaser** shall be deemed to have been delivered to, and to have become the property of the said **Purchaser,** but the **Contractor** hereby agrees to store it and to become responsible for it during the continuance of this agreement. If any of it be lost, damaged, or destroyed by floods, washouts, or fires, or by any other means whatsoever, the **Contractor** shall repair or replace the same at his own expense and to the satisfaction of the **Engineer.**

Sixth. If the **Contractor** fail to complete the work within the time specified, and if the **Purchaser** shall nevertheless permit the said **Contractor** to proceed, and continue, and complete the same, as if such time had not lapsed, such permission shall not modify nor waive in any respect any forfeiture or liability of the **Contractor** for damages arising from such non-completion of said work within the time specified, and covered by the "Liquidated Damages" clause of the specifications; but such liability shall continue in full force against the said **Contractor,** as if such permission had not been granted.

Further, if the **Contractor** fail to complete the work within the time specified, no partial estimates will be rendered and no payments will be made after the date specified for completion until the **Contractor** shall deliver to the **Engineer** for each and every such partial payment the written consent of the **Contractor's Surety,** permitting such payment to be made without affecting the validity of the Bond.

Seventh. No change or alteration shall be made in the terms or conditions of this agreement without the consent of both parties hereto in writing; and no claim shall be made or considered for any additional or unclassified work unless the same shall be authorized and directed in writing by the **Engineer.**

Eighth. The **Contractor** hereby assumes the risk of the occurrence of delays in the prosecution and completion of the work embraced in this contract; and the amounts hereinbefore mentioned to be received by the **Contractor** in payment for the work include and cover that risk, and therefore the **Contractor** shall be entitled to no additional compensation on account of any such delays.

Ninth. The **Contractor** hereby agrees that he will at all times keep within his control the work covered in this contract and will not assign or sublet all or any portion of it without the written consent of the **Purchaser.**

Tenth. The decision of the **Engineer** shall at all times control as to the interpretation of drawings and specifications for the work; but if either the **Purchaser** or the **Contractor** shall consider himself aggrieved by any such decision of the **Engineer** he may require the dispute to be finally and conclusively settled by the decision of arbitrators, one to be appointed by the **Purchaser,** and a second by the **Contractor.** In case the two arbitrators thus chosen fail to agree, a third arbitrator shall be appointed by

By the decision of these arbitrators, or by that of a majority of them, both parties to this agreement shall be finally bound.

[illegible] the infringing of any [illegible]
[illegible] be given the option of [illegible]
[illegible] the Contractor is to pay all [illegible]
[illegible] suits against the Purchaser, [illegible]
[illegible] the expenses [illegible]
[illegible]
[illegible]. The Contractor further agrees [illegible]
in force during the continuance of this contract, [illegible]
to the Purchaser, in the sum of ....
for the faithful performance of this contract, [illegible]
and conditions therein contained, and for the [illegible]
labor used in the manufacture and construction [illegible]
save harmless the Purchaser from all claims [illegible]
damages to persons or property caused by the [illegible]
the part of the Contractor, his agents, servants, or [illegible]
connection therewith, and from injury to or loss of [illegible]
either partially or in full before the completion and [illegible]
constructions.

Thirteenth. The word "Engineer" or "[illegible]
in the Specifications shall mean ....
Engineers of
or their duly authorized representative.

IN WITNESS WHEREOF, the parties to this [illegible]
hands and seals.
Dated the day and year first herein written.

....

....

....

.... } Witness of Purchaser's
.... }

....

....

....

.... } Witness of Contra
.... }

CLAUSE INDEX OF CHAPTER LXXIX

CHAPTER LXXX

GLOSSARY OF TERMS

THE dimensions to which the following glossary of technical terms used in all branches of bridgework and in its allied constructions has attained are a surprise to all concerned in its preparation. While it is intended to cover only those technical words that are employed in bridge engineering and construction, it includes all lines thereof, from the theory given in the technical schools, through the designing, manufacture of metal, and all other bridge materials, shopwork, inspection, and construction—up to the completion of the finished structure and all the accessory works, such as approaches, shore protection, operating machinery, lighting, and fire protection—also even the maintenance and operation of finished structures. On this account, many special words used in mechanical and electrical engineering and in water supply have necessarily been inserted. It has been the aim of the author to include, regardless of their evident crudity, the special nomenclature of the workmen which is not to be found in the dictionaries or other glossaries. Elaborate, though, as this glossary certainly is, it is possible that there will be found omitted some words of more or less importance, notwithstanding the extreme care that has been taken to overlook nothing. While making it complete, the aim has been to avoid padding by the exclusion of words that would be of no practical value under any circumstances. Occasionally some far-fetched term has been discarded, mainly because of the inability of all concerned properly to define it; but such cases were rare. Those simple, common, semi-technical words in everyday use, which form a part of the vocabulary of the general public as well as of bridge engineers and constructors, have been omitted, unless a special reason, such as given below, has made it necessary to include them.

Double words, like "Chinese Windlass," are defined nearly always under the noun, but a cross reference is made under the adjective. Hyphenated words are defined under the letter of the first word. Phrases are given under the dominating or most distinctive word, and are cross-referenced under the subsidiary word or words.

A group of words related to a single word appears as sub-heads under that word. In some instances, in order to preserve the uniformity of arrangement, it has been necessary to define apparently simple words in order to introduce the sub-headings in their proper places. It is believed that the grouping of sub-headings in this manner will afford the reader

a better grasp of the extent and ramifications of a subject than could be gained without such a classification.

The beginning of the preparation of this glossary dates back more than a dozen years to the time when the author conceived the idea of preparing a dictionary of technical engineering terms in English, French, German, and Spanish. The task proved to be too great for the time that could be spared, and hence was abandoned; but the list of technical terms collected for the purpose formed a good nucleus for this chapter. Later, after the writing of the book was begun, the author enlarged greatly the first list by selecting words from bridge specifications and from books on all subjects relating to steel metallurgy and to bridge engineering and construction, and also by having his numerous field engineers send in lists of special words and phrases used in erection. After all the terms were thus collected and placed in proper order, it was found that they numbered about four thousand, but the author excluded some four hundred of them, mainly because of their not being sufficiently unusual or strictly technical; after which the list was typewritten and made ready for the preparation of the definitions. This last work was done principally by the author's son and future partner, N. Everett Waddell, Esq., C.E.,* aided by Robert C. Barnett, Esq., C.E.,† and the author's brother, R. W. Waddell, Esq., C.E. Finally, the work was checked and revised by the author in person, who desires here to acknowledge with many thanks the valuable assistance and the careful and painstaking work of the three gentlemen just mentioned. They not only defined the old list of terms furnished to them, but also enlarged it fully one-third, mainly by adding derivatives, the number of terms actually defined being about five thousand, and the number cross-referenced about three thousand.

In view of the large amount of labor and the great care expended on the preparation of this glossary, it is ardently hoped by all concerned in its preparation that it will prove of real service to the engineering profession.

GLOSSARY

A

Abacus.—The upper member of the capital of a column.

Abscissa.—A term in rectangular coordinates referring to the horizontal distance of any point from the vertical axis.

Abutment.—That part of a pier from which an arch springs. A structure sustaining one end of a bridge span and at the same time supporting the embankment which carries the track or roadway.

Straight Abutment.—An abutment that has only one wall, which is generally at right angles to the longitudinal centre line of the structure.

Stub Abutment.—Same as "Straight Abutment," *q.v.*

T-Abutment.—A straight or stub abutment with a stem running back into the fill.

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* Now junior member of the firm of Waddell and Son, Consulting Engineers.

† Now Associate Engineer of Waddell and Son.

[illegible]

[illegible] Cement.—See "Cement."

[illegible]

[illegible]—The force which holds together [illegible] each other.

[illegible] Curve.—See "Curve."

Adjustable Eye-bar.—See "Eye-bar."

Adjustable Key.—See "Key."

Adjustable Member.—See "Member."

Administration.—The direction or oversight of
  or the management of public affairs.

Adulterant.—A substance substituted partially for

Adulteration.—The partial substitution of one
  ledgment.

Advancing-load Stress.—See "Stress."

Adze.—A hand tool, having a curved cutting
  for dressing the surfaces of timbers or stones.

Aeration Jet.—See "Jet."

Aggregate.—The inert material such as sand, broken
  or other adhesive material is mixed to form a

Air-blast.—An air current forced upon a fire to

Air Brake.—See "Brake."

Air Chamber.—See "Chamber."

Air Compressor.—See "Compressor."

Air Current.—See "Current."

Air Cushion.—See "Cushion."

Air Cylinder.—See "Cylinder."

Air Dolly.—See "Dolly."

Air Gauge.—See "Gauge."

Air Gun.—See "Gun."

Air Hammer.—See "Hammer."

Air Hoist.—See "Hoist."

Air Hose.—See "Hose."

Air-lift.—A hoisting apparatus that operates by means of

Air Line.—See "Line."

Air-lock.—An air-tight, double-door antechamber of a
  men or materials into or out of the caisson and to
  such passage.

Air Piston.—See "Piston."

Air Pressure.—See "Pressure."

Air Pump.—See "Pump.

Air Reamer.—See "Reamer."

Air-receiver.—A reservoir in which compressed air is

Air Riveter.—See "Riveter."

Air-setting.—Hardening by exposure to air. Usually

[illegible]

Alidade.—The horizontal plate in a transit which carries the [illegible] and the standards, and which revolves about the graduated limb; [illegible] on many instruments for measuring angles. A straight edge, having a [illegible] mounted thereon, used in plane table surveying.

Alignment.—The state of being in line; the ground plan of a railway or [illegible] in contradistinction to the grades or profile.

Alligator Riveter.—See "Riveter."

Alligator Wrench.—See "Wrench."

Allowable Bearing Pressure.—See "Bearing."

Alloy.—A substance consisting of two or more metals mixed together, or [illegible] bodies mixed with metals, in intimate solution or combination with one [illegible] forming, when melted, a homogeneous fluid.

Alternate Layout.—See "Layout."

Alternating Current.—See "Current."

Altitude.—Height; the degree or amount of elevation above the foundation or ground.

Aluminum.—A white metal with high tensile strength and low specific gravity. Used for purifying steel.

Aluminum Bronze.—An alloy of copper containing about ten per cent of aluminum.

Ambiguous Stress.—See "Stress."

American Locomotive.—See "Locomotive."

Ammeter.—An instrument for measuring or estimating in amperes the quantity of an electric current. An ampere-meter.

Amorphous.—Without regard for definite form; uncrystallised, structureless.

Amortization.—A method for liquidating a debt by making annual payments to a sinking fund which in a given time with the accumulated interest becomes equal to the debt.

Amount.—The sum of the principal plus accrued interest for a given time. In the case of a sinking fund involving periodic deposits of money, the amount of such fund is the sum of the "amounts" of the deposits.

Amplitude of Vibration.—See "Vibration."

Anchor.—An apparatus which holds a floating object to the bottom, or any device for holding an object to the ground or to other fixed objects.

Chinese Anchor.—A rectangular box filled with rocks, used for anchoring in swift currents. A sling, or bridle, is attached to the box, and to this a float is fastened.

Mushroom Anchor.—An anchor made in the shape of a mushroom—used on muddy bottom.

Anchorage.—A device for anchoring down any part subjected to uplift, such as the end of the anchor arm of a cantilever bridge.

Anchor Arm.—The end portion of a cantilever bridge extending from one of the main piers to an anchor pier.

[illegible] Bar.—See "Bar."

[illegible] Bolt.—See "Bolt."

[illegible] Pier.—See "Pier."

[illegible] Pile.—See "Pile."

[illegible] Plate.—See "Plate."

[illegible] Shackle.—See "Shackle."

[illegible] Span.—See "Span."

[illegible]—The amount of divergence between two intersecting, straight lines. The term [illegible] applied to an angle-iron section, *q.v.*

[illegible]—An angle-iron section in which one leg has a bulb on one end.

Clip Angle.—A short connecting angle

member; also termed a "lug-angle."

Connecting Angle.—An angle-iron used for

Flange Angle.—One of the upper or lower

[illegible] Angle.—An angle to which [illegible]

Lacing or Lattice Angle.—An angle used in

Lug Angle.—Same as "Clip Angle," *q.v.*

Reentrant Angle.—An angle in which the

it forms a part.

Seat Angle.—A short angle riveted to a column

during erection.

Shelf Angle.—Same as "Seat Angle," *q.v.*

Starred Angles.—A pair of angles placed

and held in position by tie-plates riveted thereto

Stiffening Angles.—Angles riveted to the web of a

Thrust Angle.—A short angle inserted between the

at the bottom of the cantilever bracket to carry the

cross-girder. An angle member in traction bracing

Angle Clip.—Same as "Clip Angle," *q.v.*

Angle-iron.—A rolled piece of steel having a cross-section

Angle Joint.—See "Joint."

Angle Lacing.—See "Lacing."

Angle Lug.—Same as "Clip Angle," *q.v.*

Angle of Friction.—See "Friction."

Angle of Repose.—See "Repose."

Angle of Rupture.—See "Rupture."

Angle of Torsion.—See "Torsion."

Angle of Twist.—Same as "Angle of Torsion," *q.v.*

Angle Strut.—See "Strut."

Angular Fracture.—See "Fracture."

Angular Strain.—Same as "Torsional Strain," *q.v.*

Angular Velocity.—See "Velocity."

Anneal.—To reduce the brittleness and increase the

to a certain temperature, then cooling slowly in air

Annealing Furnace.—See "Furnace."

Annuity.—A regular, yearly payment of a uniform sum of

Anvil.—A heavy block of steel on which metals may be

Anvil Vise.—See "Vise."

Apex.—The intersection of a web member with a chord

point.

Apex Load.—See "Load."

Apparent Stress.—See "Stress."

Approach.—The construction leading to the end of a bridge.

Apron.—A device to protect a river bank or river bed against

Ice Apron.—An ice breaker, or starling, placed on the

to protect it from the moving ice.

Aqueduct.—An artificial canal for the conveyance of water,

the ground.

Arbitration Test Bar.—See "Bar."

Arc.—A portion of a curve. An arch.

Arch.—Any bow-like curve, structure, or object, usually

generally spanning an opening and producing horizontal

Blind Arch.—An arch in which the opening is walled

Braced Arch.—An open-work truss in the form of an arch.

Catenary Arch.—An arch which takes the form of an inverted catenary, *q.v.*

Circular Arch.—An arch which takes the form of a portion of a circle.

Crown Thrust of an Arch.—The thrust or compression existing at the crown of an arch due to the loading.

Elastic Arch.—An arch designed on the basis of the elastic theory of materials.

Elliptical Arch.—An arch having the form of a semi-ellipse.

Flat Arch.—An arch in which the intrados is straight; an arch of low rise.

Geostatic Arch.—An arch which has a curve of such nature that the vertical pressure is proportional to the depth below a fixed horizontal plane, and the horizontal pressure bears to the vertical pressure a fixed ratio depending on the nature of the superincumbent materials.

Groined Arch.—An arch in which the curved intersections, or arrises, of simple vaults cross each other at any angle.

Hinged Arch.—An arch which has one or more hinged joints.

Inverted Arch.—An arch having its intrados below the axis or springing line.

Jack Arch.—An arch limited in thickness to that of one brick.

Laminated Arch.—A beam, having the form of an arch, constructed of several thicknesses of planking bent to shape and bolted together.

Lenticular Arch.—An arch which has a rib composed of two lens-shaped trusses.

Linear Arch.—A linear arch is the equilibrium polygon for the system of loads applied to the physical arch. In an actual arch the resistance line is the linear arch for the actual loading.

Melan Arch.—A type of reinforced concrete arch in which ribs of rolled I-beams, or built up lattice girders, spaced two or three feet centres, are used to strengthen the concrete arch barrel.

Monier Arch.—An arch in which the reinforcement consists of wire netting, one net being placed near the intrados and one near the extrados.

Multi-centered Arch.—An arch having an outline composed of a series of circular arcs with different radii, giving an approximation to an ellipse. These arcs are symmetrically disposed about a vertical axis and occur in odd numbers.

Oblique Arch.—An arch in which the axis is not perpendicular to the central plane of the structure.

Open Spandrel Arch.—An arch in which the roadway is carried on spandrel columns or cross-walls.

Relieving Arches.—Arches which are built at the back of a retaining wall with their axes perpendicular to the wall, in order to relieve the structure from a portion of the lateral thrust, and to increase the resistance to overturning by the additional weight of masonry and its superposed earth load.

Right Arch.—An arch in which the faces are perpendicular to the axis of the soffit.

Rise of an Arch.—The vertical distance from the springing line to the highest point of the intrados.

Segmental Arch.—A circular arch in which the intrados is less than a semi-circle.

[illegible] Arch.—Same as an "Oblique Arch," *q.v.*

[illegible] Arch.—An arch which has no openings or deep recesses in its arch barrel, and which is composed of one material or aggregate.

[illegible] Spandrel Arch.—Same as "Spandrel Filled Arch," *q.v.*

[illegible] Braced Arch.—See "Spandrel Braced."

[illegible] Filled Arch.—An arch in which the spandrels are filled with earth or [illegible] materials.

[illegible]—Knocking out the wedges and lowering the centres, thus making [illegible] supporting.

[illegible]—An arch hinged at the piers, or abutments, and at the crown.

[illegible]—See "Culvert."

[illegible]—See "Dam."

[illegible]—See "Girder."

Arch Rib.—A rigid curved beam either solid or

Arch Ring.—That portion between the

called an "Arch Barrel."

Arch Span.—See "Span."

Arch Stone.—Same as "Voussoir," q.v.

Arch Truss.—See "Truss."

Architect's Rod.—See "Rod."

Architect's Scale.—See "Scale."

Area.—The amount of surface included between
particular extent of surface, region, or tract.

Catchment Area.—Same as "Drainage Area."

Drainage Area.—The area drained by a stream or

Effective Area.—The gross area of a section less
pinholes; the net area.

Moment Area.—Sometimes called area moment.
curve. See also "Moment-Area Method."

Sectional Area.—The area enclosed by the periphery

Area Moment.—Same as "Moment Area," *q.v.*

Argillaceous.—Containing a certain amount of clayey

Arithmetical Progression.—See "Progression."

Arris.—The edge or ridge formed by the intersection of

Artificial Portland Cement.—See "Cement."

Asbestos.—A white, gray, or green-gray fibrous variety
containing but little aluminum, as tremolite or
earth flax, mountain cork, and amiantus. It is

Asbestos Packing.—See "Packing."

Asbestos Paper.—See "Paper."

Ashlar.—Large squared blocks of stone. Also frequently

Axed Ashlar.—Ashlar blocks which have been finished

Broken Ashlar.—Cut-stone masonry formed of ashlar
horizontal joints are discontinuous.

Dressed Ashlar.—Ashlar blocks in which the faces
off to a greater or less degree.

Rough Ashlar.—Ashlar blocks in which the faces are
used, rather illogically, for squared range-masonry.

Small Ashlar.—Ashlar blocks less than one foot thick.

Tooled Ashlar.—Ashlar blocks that have been dressed
tool.

Ashlar Masonry.—See "Masonry."

Asphalt.—A bituminous material employed for covering
blocks, forming surfaces of roads, etc.

Asphalter.—One who covers surfaces with asphalt.

Asphalt Furnace.—See "Furnace."

Asphaltic Mastic.—See "Mastic."

Asphalt Rock.—A limestone impregnated with bituminous material.

Asphaltum.—Same as "Asphalt," *q.v.*

Assay.—A test of the composition, purity, weight, etc., of metals or metallic substances such as ores or alloys.

Assay Balance.—See "Balance."

Assay Furnace.—See "Furnace."

Assembling Bolt.—See "Bolt."

Assembling Hoist.—See "Hoist."

Assistant Engine.—See "Engine."

Atlantic Locomotive.—See "Locomotive."

A-Truss.—See "Truss."

Auger.—An instrument for boring holes larger than those made by a bit or gimlet; consisting of a helix with cutting prongs or edges.

Crank Auger.—An auger operated by turning a crank; used on metal or wood.

Post-hole Auger.—A large size hand tool for boring holes in earth.

Ship Auger.—An auger with a long shank in which two cranks are formed.

Single Lip Screw Auger.—An auger which has a bit with only one lip or cutting edge.

Auger Bit.—A small auger used with a brace or a bit-stock.

Automatic Gate.—See "Gate."

Automatic Switch.—See "Switch."

Average End-Area Formula.—A formula for finding the approximate volume of a prismoid. Thus:

$$V = \left(\frac{A_1 + A_2}{2}\right) l$$

where V = volume,
A_1 = area of one base,
A_2 = area of the other base,
and l = the perpendicular distance between bases.

Average Haul.—See "Haul."

Awl.—A sharp, pointed tool used for punching small holes in wood or leather without removing the material itself.

Brad Awl.—A short non-tapering awl, with the cutting edge on the end, for making holes in wood to receive brads, screws, etc.

Scratch Awl.—Same as "Scribing Awl," *q.v.*

Scribing Awl.—A straight, sharp-pointed awl used for making lines on wood and metal; sometimes called a scratch-awl.

Ax or Axe.—A hand tool used for hewing timber and chopping wood, also in some forms employed for surfacing stone.

Broad Axe.—An axe with a broad blade on one side and a hammer head on the other.

Double-bitted Axe.—A double-bladed axe.

Hand Axe.—A small, short-handled axe.

Pick Axe.—A hand tool similar to a pick, but having broader blades set at right angles to each other.

Poll Axe.—An ax with a rounding blade on one side and a blunt head or pole on the other. It is the most common form of axe.

Tooth Axe.—A mason's tool with a double wedge-shaped head and teeth on the cutting edges.

Axed.—A form of stone dressing. See "Dressing."

Broken-Axed.—A form of stone dressing. See "Dressing."

Tooth-Axed.—A form of stone dressing. See "Dressing."

Axed Ashlar.—See "Ashlar."

Axed Dressing.—See "Dressing."

Axed Stone.—See "Stone."

Axe Hammer.—See "Hammer."

Axial.—Pertaining to or of the nature of an axis.

Axial Stress.—See "Stress."

Axiom.—A self evident principle or fact.

Axis.—A line about which a figure or a body is symmetrically arranged, or about which such a figure or body rotates. A principal line through the centre of a figure or solid. A fixed line along which distances are measured or to which positions are referred.

Eccentric Axis.—An axis that does not pass through the centre of gravity or the centre of figure of the body considered. The axis about which an eccentric revolves.

Longitudinal Axis.—An axis in the longitudinal direction of the figure or body considered, and generally passing through the centre of gravity or the centre of figure.

Neutral Axis.—The trace of that plane in a beam where there is no tension or compression and where no deformation takes place.

Polar Axis.—An axis at right angles to the plane of rotation.

Axis of Gravity.—See "Gravity."

Axis of Symmetry.—See "Symmetry."

Axis of Pressure.—See "Pressure."

Axis of Resistance.—See "Resistance."

Axis of Rotation.—See "Rotation."

Axle.—A pin or spindle about which any wheel or member revolves.

Blind Axle.—An axle that does not communicate power; also called a dead axle.

Driving Axle.—An axle which communicates motion to other parts of a machine. The axle of a locomotive which receives power from a steam piston through connecting rods.

Thrust Axle.—An axle subjected to a longitudinal thrust.

Axle Concentration.—See "Concentration."

Axle Load.—See "Load."

Azimuth.—The angular position of an object referred to a meridian.

B

Babbitt Metal.—See "Metal."

Baby.—A bundle of willows or other brush tied together and enclosing small rock, thrown into a stream to protect the bank. More properly termed a "fascine."

Back-filling.—See "Filling."

Backing.—A course of masonry resting on the extrados of an arch; the earth filling behind an abutment; the interior filling of any stone masonry construction.

Backing-out Punch.—See "Punch."

Back-lash.—The reaction or tendency to work backward in a pair of gears when subjected to a sudden load. The loose play between the teeth of intermeshing gears.

Back-sight.—A level observation, or sighting back, to a turning point or bench mark of known elevation. A transit observation on a previously located point in the rear. A fixed object in the rear which is sighted upon from time to time to check the orientation of the transit.

Back Speed.—The second speed gear of a lathe.

Back Stay.—See "Stay."

Back Truck Locomotive.—See "Locomotive."

Balance.—An instrument used to determine weights.

Assay Balance.—A very sensitive, accurate balance used by assayers for weighing exceedingly small quantities of materials.

Locomotive Balance.—See "Locomotive Balance."

Balance.

Spring Balance.—An apparatus for weighing articles by noting the compression of a helical spring.

Balance Beam.—The graduated bar of a balance.

Balance Block.—See "Block."

Balance Crane.—See "Crane."

Balanced Load Stress.—See "Stress."

Bale Hook.—See "Hook."

Balk.—A large beam of timber. Sometimes written "baulk."

Ball and Socket Joint.—See "Joint."

Ballast.—Gravel, broken stone, slag, or other road material put between the ties of a railroad to prevent them from slipping and to give solidity to the road.

Ballasted Floor.—See "Floor."

Ballast Hammer.—See "Hammer."

Ball Bearing.—A support designed specially for lessening friction by the use of balls partly contained in sockets, each ball being loose and turning with the object supported.

Ball Bearing Jack.—See "Jack."

Ball Check Valve.—See "Valve."

Ball Cock.—A stop-cock operated by a hollow sphere or ball of metal attached to the end of a lever which turns the stop cock of a water pipe and regulates the supply of water. Used in concrete work.

Balling Furnace.—See "Furnace."

Balling Tool.—See "Tool."

Ball Iron.—See "Iron."

Ball Joint.—See "Joint."

Ball Valve.—See "Valve."

Baltimore Truss.—See "Truss."

Baluster.—A small pillar or column, supporting a rail, of various forms, used in balustrades or hand-rails. Also called "spindles," *q.v.*

Banded Granite.—See "Granite."

B. and O.—Same as "Backing-out Punch." See "Punch."

Band Pulley.—See "Pulley."

Band Saw.—See "Saw."

Bank Discount.—See "Discount."

Bank Protection.—The prevention of erosion of a bank of a stream by the use of riprap, mattresses, or other artificial means.

Bank Sill.—See "Sill."

Bar.—Any piece of wood, metal, or solid material long in proportion to its cross-section. Also a barrier. An accumulation of silt, sand, or gravel, or a combination thereof which is deposited in streams and forms an obstruction therein.

Anchor Bar.—An eye-bar extending from the shoe of a span or tower into the concrete or masonry of the supporting pier or abutment for the purpose of holding down the span that rests thereon in case that it be subjected to uplift.

Arbitration Test Bar.—A form of small test bar used for determining the quality of material going into a casting.

Boring Bar.—A machine tool consisting of a special bar with cutters attached, used in a lathe or boring machine.

Bucking Bar.—The bar on a ring dolly which bears against a rivet, so as to hold the head during driving.

Capstan Bar.—See "Capstan."

Chisel Bar.—A heavy hand bar with a chisel edge on one end.

Claw Bar.—A hand bar with a bent, claw-shaped point for drawing spikes from railway ties or sleepers.

[illegible] Used as a pry

[illegible] bar.—A reinforcing bar

a better bond in the concrete is

Dolly Bar.—A riveter's tool or bar, used

inserted and act as an anvil while the

Extension Bar.—A bar riveted to the

it, to permit the passage of a pin.

Eye-bar.—See "Eye-bar."

Guide Bar.—One of the guides upon

bar used as a guide to a moving piece

Holding-on Bar.—A lever which is used

impact of the hammer while the other head

Kahn Bar.—A type of reinforcing bar. Its

which project from the main stem at an angle

in order to take care of the shear in the

Lacing Bar.—Any bar used in a system of

Latch Bar.—The sliding bar in the locking

Lattice Bar.—Any bar used in "Latticing," q.v.

Lock Bar.—Sheet piling which is locked together,

being used for forms.

Pick-up Bar.—A hand bar with two prongs riveted

concrete is poured, for picking up and shaking

bottom of the form.

Merchants Bar.—Wrought-iron bars in their finished

Muck Bar.—The bar made by the first rolling of the

Natural Bar.—A bar of sand or gravel formed in a

process of precipitation.

Pinch Bar.—A form of crowbar with a short projection

the end; used to pry forward heavy objects.

Puddle Bar.—Same as "Muck Bar," *q.v.*

Reinforcing Bar.—A bar or rod placed in concrete

resistance, especially to bending and shear.

Sand Bar.—A deposit of sand in a river.

Shackle Bar.—A bar used for pulling driftwood from

Shaker Bar.—Same as "Pick-up Bar," *q.v.*

Splice Bar.—The short bar used for making the joint

Spudding Bar.—A bar used to drill a hole through the

order to make an entrance for the rock drill.

Switch Bar.—A bar which connects the movable rails

Tamping Bar.—A bar used for tamping material.

Tension Bar.—Any bar subjected to tension.

Test Bar.—A sample bar used in testing the strength

Tie Bar.—A bar connecting two parts of a structure.

the two rails of a track.

Z-Bar.—A rolled steel shape having a cross-section

all angles right angles.

Barb Bolt.—See "Bolt."

Bar Buster.—See "Buster."

—A square-ended, flat-bottomed boat having capacity to carry bulky freight, such as coal and rock. Used for erecting spans by flotation.

inery Barge.—A barge which carries machinery; used in construction work.

Spike.—See "Spike."

Iron.—See "Iron."

k.—The outside covering of trees. To remove the bark from a tree, log, or pile. To scrape.

-siding.—Planks that are used to cover the outside of barns, sheds, etc. Generally boards from $^{13}/_{16}$ inch to 1 inch thick, and up to 12 inches wide.

meter.—An instrument for measuring the weight or pressure of the atmosphere.

izan.—A small turret corbelled out at the angle of a wall or tower to form a look-out. Often used in masonry or concrete bridges over the piers and abutments to afford pedestrians a place of refuge or vantage point for sightseers.

cule.—A moving span that rotates in a vertical plane about an axis that may be either fixed or movable.

Rolling Bascule.—A bascule which retreats as it rises by having a cylindrical surface roll on a plane. In some types both surfaces are toothed.

Roller-bearing Bascule.—A type of bascule which has a fixed axis of rotation and which is supported on friction rollers to reduce the resistance to turning.

Trunnion Bascule.—A type of bascule which is supported by an axle or trunnions, about which it rotates without translation.

cule Bridge.—See "Bridge."

cule-leaf.—That portion of a bascule which actually revolves in a vertical plane.

cule Span.—See "Span."

—That portion of any construction which rests on its natural support, such as the bottom of a pier or pedestal. It is generally enlarged as compared with the superimposed construction so as to reduce the intensity of the bearing pressure.

Wheel Base.—The space occupied by a group of wheels sustaining a load.

Casting.—See "Casting."

Line.—See "Line."

of Rail.—See "Rail."

Plate.—See "Plate."

Open-hearth Furnace.—See "Furnace."

Open-hearth Steel.—See "Steel."

Pig.—See "Pig."

—The angle at the cutting edge of a tool or instrument.

ing.—A finished projection around the bottom of a column located just above the ground level; similar to the baseboard of a room.

Crib.—See "Crib."

File.—See "File."

ard Granite.—See "Granite."

—A broken brick.

Bolt.—See "Bolt."

Bridge.—See "Bridge."

—A tray, generally of zinc, used for washing blue prints in a water bath.

—A strip or scantling of wood. A bar nailed across a group of parallel boards to hold them together. To tie down or fasten securely.

—A door made of sheathing, secured by strips of boards, placed cross-wise, and attached with clinched nails.

—See "Plate."

[illegible]—To strike with repeated blows, [illegible]
having a face receding as it rises. [illegible]
other construction.

Front Batter.—A forward inclination of the [illegible]
object being to allow the earth to lift [illegible]
prevent an additional horizontal pressure at the [illegible]

Batter Brace.—See "Brace."

Battered Pier.—See "Pier."

Battered Pile.—See "Pile."

Battering Ram.—See "Ram."

Batter Pile.—See "Pile."

Batter Post.—Same as "Batter Brace," *q.v.*

Battery.—A generator of electricity by the action of [illegible]

Baulk.—Same as "Balk," *q.v.*

Bauschinger's Experiments.—See Johnson's "Materials of [illegible]
man's "Mechanics of Materials."

Bay.—The portion of a trestle between two columns. [illegible]
of a truss.

Bead Joint.—See "Joint."

Beam.—A member the principal function of which is to [illegible]

Bethlehem Beam.—A special rolled beam having a [illegible]
in the Gray mill of four rolls. Manufactured by the [illegible]

Box Beam.—A hollow beam, generally rectangular in [illegible]
of plates united by angle-irons.

Built Beam.—A beam made up of structural shapes, [illegible]
riveted together.

Cantilever Beam.—A beam supported at one end only.

Collar Beam.—A horizontal timber stretching from one [illegible]
which meet at the top, and which are above the main [illegible]

Continuous Beam.—A beam that rests on three or more [illegible]

Cross Beam.—A beam which runs transversely to the [illegible]

Deck Beam.—A rolled shape having a "T" cross-section [illegible]
ment at the lower end of the stem or web.

Flitch Beam.—A compound wooden beam strengthened [illegible]

Footing Beam.—The tie-beam of a roof.

Hammer Beam.—A short beam attached to the foot of [illegible]
in place of a tie-beam.

I-Beam.—A rolled structural shape having a cross-section [illegible]

Joggle Beam.—A built-up beam having a joggle, *q.v.*

Leading Beam.—A beam placed as a guide for other beams.

Needle Beam.—A cross-beam supporting a load, used in [illegible]

Rolled Beam.—A metal beam made by a rolling process.

Simple Beam.—A beam having its ends free and resting on [illegible]

T-Beam.—A reinforced concrete-beam or a rolled structural [illegible]
section resembling the letter "T."

Tension Beam.—A beam subjected to tension as well as to [illegible]

Tie Beam.—A timber that serves as a tie between walls.

Transverse Beam.—Any beam of a bridge that passes from [illegible]
truss.

Trussed Beam.—A beam braced by one or more vertical [illegible]
rods attached to the ends of the beam.

Beam Compass.—See "Compass."

Beam Hanger.—See "Hanger."

Beam-hanger Nuts.—See "Nuts."

Beam-hanger Plate.—See "Plate."

Beam Span.—See "Span."

Beam-trussing Posts.—See "Post."

Beam-trussing Rods.—See "Rod."

Bearing.—The angular position of a line referred to a meridian. The support for a shaft, axle, or trunnion. The shoes for a span. The resistance to crushing as offered by a member. The pressure transferred from one member to another. The capacity of a pile to carry load. The support for a beam, pin, bolt, or rivet.

Allowable Bearing.—The maximum intensity of pressure on a support allowed by the specifications.

Ball Bearing.—See "Ball Bearing."

Centre Bearing.—A term applied to swing spans to indicate that the dead load support is near the axis of the pivot pier instead of near the periphery thereof.

Even Bearing.—A bearing in which the pressure is uniformly distributed.

Expansion Bearing.—A support at the end of a span where provision is made for the expansion and contraction of the structure.

Journal Bearing.—The immediate support of an axle or a shaft.

Oil Bearing.—A bearing having a reservoir for oil in its base and rings running loosely over the journal, or shaft, dipping into the oil, so that their rotation continuously carries the oil to the journal and thus provides constant lubrication.

Pin Bearing.—A type of end support for a girder or a truss in which a pin is used to transfer the load to the shoe.

Rim Bearing.—A term applied to swing spans to indicate that the dead load is supported by a circular girder near the periphery of the pivot pier instead of near its axis.

Rocker Bearing.—A bearing, or support, for solitary trestle bents or cantilever spans which permits of a slight rocking with the changing position of the live load and with variations of temperature.

Roller Bearing.—A shoe or plate resting on rollers which in turn rest on a base casting at the expansion end of the span.

Sand Bearing.—A bearing of confined sand used for the purpose of lowering the object that is temporarily supported. The lowering is effected by permitting the sand to escape. Also the support for the core in a sand mould for casting.

Shaft Bearing.—A support for a revolving shaft.

Sliding Bearing.—A bearing constructed so that one part slides on another.

Thrust Bearing.—A support for a shaft adapted to take up the end thrust therefrom.

Bearing Pile.—See "Pile."

Bearing Plate.—See "Plate."

Bearing Point.—The point of support for a load or a place where concentrated pressure is applied.

Bearing Pressure.—See "Pressure."

Bearing Stress.—See "Stress."

Beater.—A bridgeman's term for a maul.

Becket.—A short piece of rope with a knot at one end and a loop, or eye, at the other. A handle made of a rope sling. An iron U-strap fixed to a pulley block, so as to provide a loop for attaching a rope.

Becket Bend Knot.—Same as "Sheet Bend Knot." See "Knot."

Becket Block.—See "Block."

Becket Hitch.—A fisherman's knot. See "Knot."

Bed.—A surface or body of rock, earth, or shale which serves as a foundation. The foundation piece on which a machine rests. A layer of cement or mortar in which the stone is embedded. To place stone or brick in mortar. To embed. To place a thing on its bearing.

[illegible]

[illegible]—The solid rock lying under

[illegible] "Stone."

[illegible]—A heavy wooden mallet used to drive

[illegible]—To make fast around a belaying-pin

[illegible]—A wooden or iron pin to which

[illegible] Tank Locomotive.—See

Bell.—The large end of a pipe or tube turned out

Bell and Hopper.—A charging device on top

Bell Crank.—See "Crank."

Bellows.—An apparatus or box with flexible leather a valve that it may be opened and closed of air.

Belt.—A course of stones or bricks projecting horizontal plane. Sometimes called a rubber, or any other material which passes etc. for transmitting motion from one to the

Driving Belt.—A band, rope, strap, or belt which to another, or from one part of the same machine

Belt Course.—See "Course."

Belted.—Driven by a belt.

Belting.—The material from which belts are made. of belts taken collectively.

Link Belting.—A belt for the transmission of power, able links.

Belt Saw.—Same as "Band Saw." See "Saw."

Bench.—A table upon which mechanics do their work; an earth cutting in order to strengthen it.

Bench Dog.—See "Dog."

Bench-mark.—A mark cut in a rock or located on the elevation at that place in a line of levels.

Bench-table.—A low stone seat carried around a wall.

Bench Vise.—See "Vise."

Bend.—A band or clamp of metal used to strengthen a bending, or the state of being curved.

Bending Moment.—See "Moment."

Bending Slab.—See "Slab."

Bending Stress.—See "Stress."

Bending Test.—See "Test."

Bends.—A pneumatic caisson disease, due to the species of temporary paralysis.

Bent.—A condition of being curved or kinked. A support or piles with bracing, caps, and sills.

Cluster Bent.—A bent having a cluster of piles driven concentrations.

Column Bent.—A bent composed of columns and "pile bent."

Bent.

Framed Bent.—A bent composed of framed timbers.

Pile Bent.—A bent having piles for supporting posts.

Rocker Bent.—A bent generally of steel, though sometimes of timber, hinged at either one or both ends so as to provide for the expansion and contraction of the span supported.

Solitary Bent.—A single bent of a trestle that is not attached to either adjacent bent except by the girders of the deck.

Timber Bent.—Same as "Framed Bent," *q.v.*

Trestle Bent.—In trestle construction, one of a series of bents carrying a deck.

Bent Club Dolly.—See "Dolly."

Bent-eye.—An eye on the end of a bar, the plane of which makes an angle with the direction of the bar. Formerly used in bridges, but now abandoned as unscientific.

Bent Linked Chain.—See "Chain."

Bent Loop.—See "Loop."

Berm or Berme.—The portion of the supporting soil of an embankment lying between the toe thereof and the side-ditch.

Berm Stakes.—See "Stakes."

Bessemer Furnace.—See "Furnace."

Bessemer Pig.—See "Pig."

Bessemer Process.—A process for making steel by the decarburization of crude pig iron by means of a finely divided air current blown through the metal when in a molten state. Named from its inventor Sir Henry Bessemer.

Bessemer Steel.—See "Steel."

Bethlehem Beam.—See "Beam."

Bethlehem Column.—See "Column."

Béton.—A mixture of lime, sand, and gravel forming a kind of concrete. Sometimes used as a synonym for concrete.

Béton-Coignet.—A mixture of Portland cement, siliceous hydraulic lime, and clean sand mixed together with fresh water. See "Cement." Named after its French inventor, a Monsier Coignet.

Bettle.—a heavy wooden rammer. A workmen's corruption of "Beetle."

Bevel.—The slope on the end of a piece; an instrument for drawing angles—used by mechanics. To slope or sharpen an edge.

Beveled-edge.—An edge that is made thin by bevelling.

Beveled Gear.—See "Gear."

Beveled Gear Jack.—See "Jack."

Beveled Joint.—See "Joint."

Beveled Tie.—See "Tie."

Beveled Washers.—See "Washers."

Beveled Wheel.—See "Wheel."

Bicalcic Silicate.—See "Silicate."

Bid.—To make a price on anything. A proposition, either verbal or written, for doing work.

Unbalanced Bid.—A bid in which some of the unit prices are abnormal, either too high or too low, or generally both.

Bight.—A loop of a rope in distinction from the ends; any bent part or turn of a rope between the ends.

Billet.—A small bloom; a short, chunky bar of iron or steel.

Bill of Material.—A list of the various portions of material for a construction, either proposed or completed, giving dimensions and weights or other quantitative measurements.

Bin.—A place for storing materials, such as cement, sand, or broken stone.

Cement Bin.—A bin, usually at the cement mills, in which cement is stored for aging.

[illegible].—A substance [illegible]
component parts of the mass [illegible]
used in reference to pavements,

Binder Course.—See "Course."

Binding Joists.—See "Joists."

Binocular.—A double telescope for the use of both

Bird's-mouth Joint.—See "Joint."

Bit.—A tool for boring into wood or metal.

Bite of a Line.—The enclosed space between
a pulley-block or a hook.

Bitt.—A strong post of wood or iron to which

Bitumen.—Any native mixture of hydro-carbons,
asphalt.

Bituminous Cement.—See "Cement."

Bituminous Concrete.—See "Concrete.

Black Lead.—See "Lead."

Black-lead Graphite.—Same as "Graphite," *q.v.*

Blacksmith's Forge.—See "Forge."

Blackwall Hitch Knot.—See "Knot."

Blank Bolt.—See "Bolt."

Blast Furnace.—See "Furnace."

Blast Pipe.—See "Pipe."

Bled Ingot.—See "Ingot."

Blind Arch.—See "Arch."

Blind Axle.—See "Axle."

Blind Header.—See "Header."

Blister.—To raise filmy vesicles on a surface by heat.
surface with a void beneath.

Blister Steel.—See "Steel."

Block.—Any obstruction or cause of obstruction;
matter usually with one or more plane faces; such
etc. A combination of a frame with one or more
therein; used in connection with ropes to
block." To obstruct. To support with blocks,

Balance Blocks.—Small blocks used on counter
adjustment in counterbalancing the span.

Becket Block.—A hoisting block having a becket to

Camber Blocks.—Blocks of wood or wedges of steel
camber to a span, and so placed as to be easily

Cedar Block.—A paving block, usually round, made

Chain Blocks.—See "Chain Blocks."

Chock-a-block.—The condition of a set of blocks
go no closer together. Called also "block and block

Chock Block.—A device for stopping the motion of the
machine.

Differential Block.—A double block having sheaves

Double Block.—A pulley block having two sheaves.

Fall Blocks.—Pulley-blocks used with ropes or "fall-

Foot Block.—A heavy casting which supports the
its turning.

Gate Block.—Same as "Snatch Block," *q.v.*

Gin Block.—A simple form of tackle block having a
runs.

Guide Block.—Same as "Guide Bar." See "Bar."

Hoisting Block.—The lower pulley block of the block and falls, carrying the hoisting hook.

Hook Block.—A pulley block fitted with a hook at one end.

Lead Blocks.—Blocks for guiding ropes or for holding them in a given position without impeding their motion. The blocks through which the lead lines run.

Link Block.—A block in a steam engine attached to a valve stem.

Pedestal Block.—Same as "Base Casting;" see "Casting." Also a stone block to support a column.

Pillow Block.—A type of journal bearing having a removable cap. Also called a plummer block.

Plummer Block.—Same as "Pillow Block," *q.v.*

Pulley Block.—A movable block or frame supporting and partially enclosing one or more grooved pulleys or sheaves.

Purchase Block.—A double-strapped pulley block having two grooves in the shell.

Quadruple Block.—A block containing four sheaves either arranged side by side or in tandem fashion.

Running Block.—A movable block in a system of tackles.

Saucer Block.—A cast iron or steel block dished, or saucer shaped, in which a capstan or the bottom of a boom rests and turns around.

Shoe Block.—A form of pulley block. Also same as "Base Casting," *q.v.*

Shoulder Block.—A sheave in a frame having a shoulder to prevent the rope through the block from becoming jammed.

Single Block.—A pulley block containing one sheave only.

Sister Block.—A block having two sheaves, arranged in tandem.

Snatch Block.—A pulley block with one side capable of being opened for the insertion of a rope. It is used principally to change the direction of a running line.

Standing Block.—A pulley block fixed to some permanent support.

Tail Block.—An accessory pulley block having a rope fastened around the shell to take the place of the usual becket.

Triple Block.—A block having a set of three sheaves.

Truss Block.—A bearing block of metal placed between the truss rod and the strut of a trussed beam.

Block and Block.—The condition of the two blocks in a tackle when drawn up close together. Also called "Two Blocks" and "Chock-a-block."

Block and Falls.—A set of pulley blocks with hemp ropes or steel cables roven through them; used for hoisting purposes or for exerting a strong pull. Also called "Block and Tackle."

Block and Tackle.—Same as "Block and Falls," *q.v.*

Block Brake.—See "Brake."

Blocking.—The set of blocks which is placed under anything to raise and support it.

Blocking Hammer.—See "Hammer."

Bloom.—A roughly prepared mass of iron or steel nearly square in section and comparatively short in proportion to its thickness.

Bloomed.—Made into blooms.

Blooming Rolls.—Rolls in which puddle balls of iron or steel are squeezed into blooms.

Blow.—That portion of the time occupied by a certain stage of a metallurgical process in which the blast is used. To explode. In caisson work the term "blow" refers to the letting of air out of the working chamber so that the caisson may drop.

Blow Gun.—See "Gun."

Blowhole.—A defect in iron or steel caused by the escape of gas or air while [illegible]

[illegible] Mortar.—See "Mortar."

[illegible]

[illegible]—See "Pipe."

[illegible]—See "Print."

[illegible] Printing.—A method of photo-printing [illegible] of potash.

[illegible] Print Paper.—See "Paper."

[illegible] Iron.—See "Iron."

[illegible]—A condition of brittleness in [illegible] worked at a blue heat.

[illegible] File.—See "File."

[illegible]-measure.—The standard measure for [illegible] square and one inch thick. Timber is sold [illegible] measure usually written "per M.B.M."

[illegible] Dressing.—See "Dressing."

[illegible]—A mason's process of dressing the [illegible] and mallet.

Boat Bridge.—Same as "Pontoon Bridge." See

Boat Hook.—See "Hook."

Boat Knot.—See "Knot."

Boat Ratchet.—See "Ratchet."

Boat Spike.—See "Spike."

Bogie.—A small truck, or carriage, running [illegible] the log at right angles to its length when on the

Bog Iron.—See "Iron."

Boil.—To bubble up or be in a state of ebullition [illegible] or vortex in a stream.

Boiler.—A vessel or receptacle in which any liquid is

Locomotive Boiler.—A form of steam boiler in [illegible] number of flues with the smoke box under the

Boiler Plate.—See "Plate."

Boiler Steel.—See "Steel."

Boiling Test.—See "Test."

Bollman Truss.—See "Truss."

Bolster.—A perforated wooden block upon which sheet [illegible] A sleeve-bearing through which a spindle passes. [illegible] of a car truck to support the body. In stone [illegible] blocks against which the ends of the pole of the [illegible] pieces of an arch centering. A timber or thick [illegible] end of a bridge and its seat on the abutment.

Corbel Bolsters.—Bolsters made in the form of corbels.

Bolt.—A cylindrical jet, as that of water. A metallic [illegible] end and a thread on the other for screwing up a nut, [illegible] or parts of members together.

Anchor Bolt.—A round, steel bolt embedded in concrete [illegible] machinery, castings, shoes, spans, engine beds, etc.

Assembling Bolt.—A threaded bolt for holding together [illegible] of a structure during riveting.

[illegible] having jagged edges so as to prevent its being [illegible] the object into which it is driven. Also called a rag bolt.

[illegible] Bolt.—A bolt barbed or jagged at the butt, or tang, to give it a firmer hold.

[illegible] Bolt.—A bolt having a fixed head, but no threads nor nuts.

[illegible] Expansion Bolt.—A bolt with a screw attachment and a screwed collar over it. This bolt is used in concrete after hardening. A hole is driven, the collar inserted, and then the bolt is screwed in.

Clinch Bolt.—A bolt with one of its ends designed to be bent over to prevent withdrawal.

Construction Bolt.—A common steel bolt used temporarily during construction, such as a bolt to hold forms together.

Cotter Bolt.—Same as "Cotter Pin," *q.v.*

Countersunk Bolt.—A bolt having its head beveled and flattened, so that when put into place the said head will not project from the surface.

Drift Bolt.—A short rod or square bar to drive into holes bored in timber for attaching adjacent sticks to each other or to piles. The length generally varies from one foot to two feet. A drift bolt may or may not be provided with a head or with a sharpened end.

Expansion Bolt.—Any bolt similar to the "Brohard Expansion Bolt," *q.v.*

Eye Bolt.—A bolt having a loop or eye at one end in place of the customary flat head.

Fish Bolt.—A bolt for securing a fish joint.

Fitting-up Bolt.—An ordinary bolt used to hold steel members together while the same are being riveted.

Floor Bolt.—A bolt used in the construction of a floor.

Fox Bolt.—A masonry bolt having either a head or a thread and nut at one end and a split with inserted wedge at the other. After the bolt, with the wedge inserted in the split, is placed in the hole it is driven down so as to spread the end; then it is grouted in.

Grip of a Bolt.—The length of a threaded bolt measured from inside of the head to inside of the nut when the latter is screwed on far enough to provide full thread.

Hacked Bolt.—A bolt which has been notched with a hatchet to use as a fox bolt.

Hook Bolt.—A bolt having one end in the form of a hook.

Joint Bolt.—A bolt joining one timber to another in a "T" form.

Key Bolt.—Same as "Cotter Pin." See "Pin."

Lewis Bolt.—A wedge-shaped-ended bolt inserted like the shank of a lewis in a hole drilled in a stone and fastened therein by pouring melted lead into the unoccupied part of the hole. An eye-bolt similarly inserted and used like a lewis for lifting heaving stones. See "Lewis."

[illegible] Bolt.—A round bolt to which is welded a flat iron bar.

[illegible] Bolt.—A threaded bolt having a straight shank and a square or hexagonal [illegible] head.

[illegible] Bolt.—A bolt which holds together the several parts of a composite member.

[illegible] Bolt.—Same as "Barb Bolt," *q.v.*

[illegible] Bolt.—Same as "Eye Bolt," *q.v.*

[illegible] Bolt.—A bolt having a square head for turning with a wrench and a wood [illegible] on the opposite end for entering wood. A form of lag screw.

[illegible] Bolt.—A bolt from which the threads have been stripped.

[illegible] Bolt.—Same as "Stud Bolt," *q.v.*

[illegible] Bolt.—A threaded rod or bolt binding together opposite plates to enable them [illegible] each other against opposing pressure, as the stay bolt in a boiler.

[illegible] Bolt.—A small bolt having a rounded head, notched for a screw driver, at one [illegible] a square nut at the other.

[illegible]

[illegible] Bolt.—A bolt [illegible]
by side, a washer or separator [illegible]
connected in order to let the [illegible]
Usually these stringers are bolted [illegible]
to a composite stringer.

Stud Bolt.—A bolt with a thread cut at [illegible]
part at one end, leaving the other end [illegible]

Sway Bolt.—A bolt which fastens the sway [illegible]

Swedge Bolt.—A bolt having a thread and [illegible]
recesses at the other, used by some railways [illegible]

Tap Bolt.—A bolt which is screwed into the [illegible]
screwed by a nut. Also called a tap screw.

Through Bolt.—A bolt which passes from [illegible]
fastens.

Tie Bolt.—A round bolt with a square [illegible]
of stringers.

Timber Bolt.—Any bolt used in connecting timbers,

Toggle Bolt.—A bolt connecting the parts of a [illegible]

Track Bolt.—A bolt used for connecting railway [illegible]
an elliptical shank and a hexagonal nut. Often a [illegible]

Turned Bolt.—A machine bolt, ordinarily with [illegible]
when put in place it has a driving fit.

U-Bolt.—A rod bent in the shape of the letter U [illegible]
ends.

Bolt Eye.—See "Eye."

Bolt Head.—See "Head."

Bonanza Tile.—See "Tile."

Bond.—Anything that binds, fastens, or holds together [illegible]
connection of one stone to another. A certificate of [illegible]
of a capital debt due by a government, a city, a [illegible]
individual holders, and usually bearing a fixed [illegible]
connection, such as a bar of copper wire soldered [illegible]
junction. Also the manner of laying bricks or [illegible]

Chain Bond.—A bond formed by binding a chain, a [illegible]
masonry.

Cross Bond.—A masonry bond in which a course [illegible]
the ends where headers are used, is covered by a [illegible]
with stretchers.

English Bond.—Same as "Old English Bond," *q.v.*

Flemish Bond.—A bond consisting of a header [illegible]
course, but so placed that the outer end of each [illegible]
stretcher in the course below.

Header and Stretcher Bond.—A form of masonry [illegible]
stretchers alternating in the same row.

Heart Bond.—A masonry bond in which two headers [illegible]
meet in the middle of the wall, and have another [illegible]
them.

Old English Bond.—A masonry bond formed by [illegible]
of headers or stretchers. Sometimes, though, only [illegible]
for every two or three courses of stretchers.

Random Bond.—A bond in which the stones or [illegible]
at all.

lated Bond.—A form of masonry bond in which the stones are square and are laid lozengewise, so that the joints resemble the meshes of a net.

Lock Bond.—A bond in an arch of concentric rings, formed by laying the bricks in each ring as stretchers leaving only the mortar to unite the several rings.

Resistance.—See "Resistance."

Stress.—See "Stress."

ng.—A method used by carpenters and masons to determine whether a surface is in or out of wind. It consists in placing two similar straight edges on the surface, parallel to each other, and sighting over their upper edges to see if they coincide. If they do not, the surface is in wind.

net.—A cap over the end of a pipe. A cast-iron plate bolted down as a covering over an opening.

m.—A long beam or spar projecting from near the foot of a derrick, and sustaining the load that is raised from its outer end. In England the term is used as a synonym for a chord of a truss.

Chicago Boom.—An erector's hoisting apparatus, consisting of a timber or steel boom, without a mast, having a goose-neck casting on the lower end working in a saucer block on a temporary sill, and held in position by blocks and tackle attached to other parts of the structure.

Derrick Boom.—The long member in a derrick which supports the load at its outer end.

Brace.—A tackle extending from the end of the boom to the top of the mast in a derrick. The trussing placed below or at the sides of the boom to strengthen it.

Guy.—A line, cable, or adjustable rod fastened to the middle of a derrick boom and extending to the bull-wheel to which it is attached so as to act as a brace.

Iron.—A circular iron ring on the end of a mast of a derrick.

-out.—The position of the boom at its greatest reach.

-seat.—The place in a derrick where the boom and the mast meet and rest on the sill.

Tackle.—See "Tackle."

—To make a hole in any material by cutting away a part of it. To drill. The calibre, or internal diameter, of a hole, tube, or pipe.

—Any hole that has been bored, such as a boring for a pier foundation.

Core Boring.—A boring made by a core-drill by means of which samples of the material passed through, in the shape of a cylinder or core, are brought to the surface for inspection.

Boring.—A boring made by a churn drill by means of which samples of the material penetrated, in granular form, are washed to the surface by a flow of water.

Bar.—See "Bar."

Casing.—See "Casing."

Machine.—A machine used for boring holes.

Boring Machine.—A boring machine used in bridge shops for boring pin-holes in chords.

Boring Machine.—An apparatus, generally run by air, for boring holes in timbers.

Mill.—See "Mill."

pit.—An excavation made by the removal of material, specially for use in filling or in building an embankment.

A rough sketch, an outline, or a figure. A trough in which bloomery tools are

enlarged part of a shaft on which a wheel is keyed. A wooden vessel used for holding mortar. A foreman or sub-foreman. One who directs

[illegible]

[illegible] cap that covers the top of a

shaft or journal. A casing about a

a box.

Coupling Box.—The box or ring of

lengths of shafting.

Driving Box.—The journal box of a

Journal Box.—A one-piece box or bearing

Mortar Box.—A box in which mortar is

Oil Box.—A box attached to certain types

with oil.

Packing Box.—Same as "Stuffing Box," q.v.

Resistance Box.—A box containing

Roller Box.—An iron or steel box holding

Shafting Box.—A one-piece type of bearing

holes for bolting to a support.

Stuffing Box.—A device for securing a

about a movable rod. It consists of two

and so arranged that packing of some kind

and compressed, by means of tightening the

rod.

Tool Box.—A box for holding tools, generally

for convenience in carrying it about.

Box Beam.—See "Beam."

Box Column.—See "Column."

Box Culvert.—See "Culvert."

Box-drain.—Same as "Box Culvert," *q.v.*

Box Girder.—See "Girder."

Box Strut.—See "Strut."

Brace.—Generally a strut supporting or fixing in

times the term is applied to a tie used for such a

of a small tool used for boring.

Batter Brace.—The inclined end post of a truss,

Boom Brace.—See "Boom."

Knee Brace.—Same as "Knee," *q.v.*

Tension Brace.—A brace which resists tension.

Braced.—Strengthened or well interlaced and linked

Braced Arch.—See "Arch."

Bracer.—A brace.

Bracing.—A system of braces, as in lateral systems.

Bottom Lateral Bracing.—Lateral bracing in the

truss.

Cross Bracing.—Same as "X Bracing," *q.v.*

Diagonal Bracing.—Bracing along diagonal lines.

Bracing.

Horizontal Bracing.—Bracing lying in a horizontal plane.

Horizontal Sway Bracing.—Sway bracing in a horizontal plane.

Ladder Bracing.—Bracing consisting of struts only.

Lateral Bracing.—A system of tension or compression members, or both, forming the web of a horizontal truss connecting the homologous chords of the opposite trusses of a span.

Longitudinal Bracing.—Bracing extending lengthwise of the structure, or parallel to its centre line.

Lower Lateral Bracing.—Same as "Bottom Lateral Bracing," *q.v.*

Overhead Bracing.—The upper lateral or the vertical sway bracing in through bridges. The term is usually applied to the vertical sway bracing, if there be any; if not, to the upper lateral bracing.

Portal Bracing.—The combination of struts and ties in the plane of the end posts at a portal which helps to transfer the wind pressure from the upper lateral system to the pier or abutment.

Side Bracing.—The bracing on the sides of falsework, of a timber trestle, or of a pony-truss bridge.

Stringer Bracing.—Diagonal bracing in the plane of the upper flanges of the stringers.

Sway Bracing.—Bracing transverse to the planes of the trusses; used to resist wind pressure and to prevent undue vibration.

Top Lateral Bracing.—Lateral bracing in the plane of the top chords.

Tower Bracing.—Bracing attached to the posts of towers.

Traction Bracing.—Same as "Train-thrust Bracing," *q.v.*

Train-thrust Bracing.—Bracing in the plane of the bottom laterals which transfers the thrust of a braked train from the stringers to the trusses.

Transverse Bracing.—Bracing which is perpendicular (or but slightly inclined) to the centre line of the structure.

Upper Lateral Bracing.—Same as "Top Lateral Bracing," *q.v.*

Vertical Bracing.—Wind bracing lying in a vertical plane, such as sway bracing

Wind Bracing.—Bracing which takes up the stresses induced by the wind.

X-Bracing.—Any system of bracing in which the diagonals intersect.

Bracing Frame.—A frame of steel or timber built in a manner to withstand distortion.

Bracket.—A knee, or knee brace, connecting a post or batter brace to an overhead strut.

Cantilever Bracket.—A bracket cantilevered out from another member.

Corner Bracket.—A steel bracket rigidly attached in a re-entrant corner of a structure.

Bracket Crab.—See "Crab."

Brad Awl.—See "Awl."

Bragger.—Same as "Corbel," *q.v.*

Brake.—A mechanical device for arresting or retarding the motion of a machine or vehicle by means of friction. To retard or stop motion by the application of a brake.

Air Brake.—A system of braking mechanism operated by compressed air.

Block Brake.—A brake used in retarding a moving part by pressure from a stationary block.

Friction Brake.—Same as "Prony Friction Brake," *q.v.*

Prony Friction Brake.—A brake used for measuring the effective power developed by an engine or turbine.

Solenoid Brake.—A combination of a solenoid and a movable iron core which is drawn into the helix when the electric current is flowing, thereby actuating the brake mechanism.

Braked-train.—A train in motion with the brakes set and the steam shut off.

Brake Horsepower.—See "Horsepower."

[illegible]

[illegible]

[illegible]

Journal Brass.—One of the [illegible] in a journal box.

Braze.—To cover with brass. To [illegible]

Breach.—A break, as a breach of contract, [illegible]

Breaking Joint.—See "Joint."

Breaking Load.—See "Load."

Break in Grade.—See "Grade."

Breaking Stress.—See "Stress."

Break Joint.—See "Joint."

Breakwater.—Any structure, such as a mole, [illegible] the force of waves and protect harbors.

Breast Plate.—A plate on a tool for the [illegible] plate on a hand drill.

Breast-summer.—A beam of wood, iron, or stone [illegible] opening; a kind of lintel. Called also [illegible]

Breast Wall.—See "Wall."

Brick.—A kind of artificial stone made of [illegible] into rectangular blocks and hardened by [illegible]

Carborundum Brick.—A brick of carborundum [illegible] furnace and used for smoothing or polishing.

Cement Brick.—A brick made out of cement [illegible]

Clinker Brick.—Brick that forms the tops [illegible] and consequently is directly exposed to the [illegible] vitrified, clinker bricks are hard, brittle, and [illegible]

Compass Brick.—A brick having one edge shorter [illegible] shafts, etc.

Concave Brick.—A brick of special form with [illegible] making arches.

Dutch Brick.—A dirty-looking, brimstone brick [illegible]

Facing Brick.—Brick suitable for the exterior of [illegible] is required.

Feather-edge Brick.—Same as "Compass Brick," *q.v.* [illegible]

Fire Brick.—A brick made of pure clay (or pure [illegible] high temperatures.

Flemish Brick.—A species of hard yellow brick used for [illegible]

Hand Brick.—A scrubbing brick for hand operation.

Pale Brick.—Under-burned brick and, therefore, lighter [illegible] brick.

Paving Brick.—Any hard brick used in paving.

Pressed Brick.—A brick moulded from dry or semi-dry [illegible] until it is very hard and smooth.

Sewer Brick.—Ordinary hard brick, smooth and regular [illegible] construction.

Slop Brick.—An old-time brick made by depositing [illegible] smoothing off the top with a wet stick run over the [illegible]

Vitrified Brick.—A glazed brick, made by fusing a silicious [illegible]

Bricklayer's Hammer.—See "Hammer."

Brick Masonry.—See "Masonry."

Brick Pier.—See "Pier."

Bridge.—A structure that spans a body of water, a valley, [illegible] for pedestrians, or vehicles of all kinds, or any [illegible]

Bridge.—A curved structure which produces reactions inclined to the vertical.

le Bridge.—A bridge having a span that opens by rotating in a vertical plane.

Bridge.—A floating bridge supported by boats or barges. A pontoon bridge.

Bridge.—Same as "Bateau Bridge," *q.v.*

tilever Bridge.—A structure at least one portion of which acts as an anchorage for sustaining another portion which projects beyond the supporting pier.

in Bridge.—A suspension bridge in which chains are employed instead of the usual cables.

mbination Bridge.—A bridge constructed of timbers and steel or iron.

mbined Bridge.—A bridge which carries both railway and highway traffic.

ck Bridge.—A bridge in which the passing loads are carried directly to the upper chords or to the upper portions of the posts.

w Bridge.—A bridge that may be drawn or turned to one side, or lifted up, either dily or in sections, so as to permit boats to pass under or through it.

d Bridge.—One that does not move except for expansion and contraction

ing Bridge.—Same as a "Jack-knife Bridge," *q.v.*

Bridge.—A bridge for foot passengers only.

me Bridge.—A bridge constructed of sticks of timber framed together.

der Bridge.—A bridge composed of plate or lattice girders.

ging Bridge.—Same as "Suspension Bridge," *q.v.*

Bridge.—A bridge over navigable water having ample clearance beneath it to rmit the passage of all vessel traffic without moving a span or any portion of one.

hway Bridge.—A bridge that carries highway traffic only.

Lift Bridge.—A lift bridge which has its ends hinged together when down.

Bridge.—Same as "Lift Bridge," *q.v.*

am Bridge.—A small bridge consisting of a floor supported on I-beams.

k-knife Bridge.—A bridge in which the lifting arms fold on themselves at midgth when in a raised position.

ice Bridge.—A bridge having riveted trusses with multiple intersection web mbers.

f Bridge.—A form of draw bridge in which the rising leaf, or leaves, swing vertically on hinges.

Bridge.—A bridge resting on legs, formed by a downward extension of the end posts, instead of masonry abutments.

Draw Bridge.—A draw bridge operated by means of a lever.

Bridge.—A type of movable bridge which travels in a vertical plane, sometimes lled a hoist bridge.

g Bridge.—Same as "Lift Bridge," *q.v.*

Bridge.—A bridge over navigable water so low that some vessels cannot go neath it without an opening passage being provided in the structure.

Bridge.—A draw bridge operated by a motor, or a bridge which carries motor

Bridge.—A bridge with a "Movable Span." See "Span."

Bridge.—A bridge consisting of pile bents and timber caps, stringers and bracing.

Bridge.—A platform or roadway supported on pontoons or barges. A ting bridge.

k Draw Bridge.—A movable span which retreats longitudinally to allow the of vessels.

Bridge.—A bridge which carries railway traffic.

Draw Bridge.—A draw bridge which turns in a horizontal plane.

Draw Bridge.—Same as "Pull-back Draw Bridge," *q.v.*

Bridge.—A bascule bridge in which the moving arm rolls on a plane rollers.

[illegible]

[illegible] Bridge.—A bridge with

elevation of the bottom chords.

Trestle Bridge.—A bridge composed

of either timber or metal.

Truss Bridge.—A bridge made up of

Tubular Arch Bridge.—A bridge in which

tubes.

Tubular Bridge.—A plate-girder structure

and bottom, forming a boxed space

Turning Bridge.—Same as "Swing Bridge,"

Vertical Lift Bridge.—A bridge having a

Wagon Bridge.—Same as "Highway Bridge,"

Bridge Guard.—See "Guard."

Bridge-seat.—That part of the top of a bridge

the pedestals or shoes of the superstructure.

Bridge Tape.—See "Tape."

Bridge Truss.—See "Truss."

Bridging.—A piece of wood placed between and

in order to prevent them from approaching

of any opening.

Bridging Joists.—See "Joists."

Bridging Stone.—See "Stone."

Briggs Logarithm.—See "Logarithm."

Briquette.—A standard shaped form or block made of

and sand; used for testing the tensile strength of

Cement Briquette.—A briquette made of cement

strength of the cement.

Neat Briquette.—Same as "Cement Briquette," q.v.

Sand Briquette.—A briquette made of sand and

Briquette Clips.—See "Clips."

Briquette Mould.—See "Mould."

Bristol-board.—A high quality of calendered cardboard

etc.

Brittle-zone.—In nickel steel testing, the stage between

limits for percentage of nickel in the alloy where

below and above which it is not.

Broach.—A boring bit or tapering tool for enlarging and

Also a narrow-pointed chisel for dressing stone.

Broached Dressing.—See "Dressing."

Broad Axe.—See "Ax or Axe."

Brohard Expansion Bolt.—See "Bolt."

Broken Ashlar.—See "Ashlar."

Broken Ashlar Masonry.—See "Masonry.'

Broken Axed.—A form of stone dressing. See "Dressing."

Broken Axed Dressing.—See "Dressing."

Broken Coursed Rubble.—See "Rubble."

Broken Line.—See "Line."

Broken Ranged Rubble.—See "Rubble."

Broken Range Masonry.—See "Masonry."

Broken Stone.—See "Stone."

Broken Stone Concrete.—See "Concrete."

Broken Top Chord.—See "Chord."

Bronze.—A reddish-brown alloy of copper and tin, sometimes containing small portions of other metals. Used in bridgework for journal or pivot bearings and for nameplates.

Bronze Steel.—See "Steel."

Brooming.—The breaking up under hammering of either the head or the point of a timber pile and reducing it to a fibrous mass.

Brushes.—The copper wires, plates, or carbon connections which make contact with the commutator on a dynamo or motor and serve to take off the electric current.

Bubble.—The vesicle of air or gas in the glass spirit-tube of a mechanic's or surveyor's level. A blister on a steel surface.

Buck.—To resist. To afford resistance. To press against a rivet-head with a dolly during driving.

Buck Brace.—Same as "Cross Frame." See "Frame."

Bucker-up.—One who holds a dolly-bar on the head of a rivet while it is being driven.

Bucket.—A vessel for drawing up water or materials, as from a well. One of the scoops of a dredging machine. In general terms, any contrivance used for carrying materials in hoisting.

Clam Shell Bucket.—A dredging bucket composed of two curved leaves hinged about a point at their top and so arranged as to open or shut at the will of the operator.

Collapsing Bucket.—A bucket which can be made to drop its burden by folding or collapsing.

Grab Bucket.—Any dredge bucket that opens up and grabs its loading.

Orange Peel Bucket.—A dredging bucket composed of four curved and tapered pieces, hinged at their tops and so arranged that when closed they form a large cup for carrying materials. When opened to their full extent, four tooth-like prongs are presented for digging into the material. Loading is completed by closing up the four prongs or leaves.

Bucket Dredge.—See "Dredge."

Bucket Hole.—The hole or shaft in which a bucket travels.

Bucket Pump.—See "Pump."

Buckle.—To bend in a lateral direction by a longitudinal pressure.

Buckle Plate.—See "Plate."

Buckle Plate Floor.—See "Floor."

Buckle Plate Press.—See "Press."

Buckling Stress.—See "Stress."

Buffer.—Any apparatus for deadening the concussion between a moving body and another body against which it strikes.

Hydraulic Buffer.—An automatic device for checking recoil by means of water or other liquid forced under high pressure through a small aperture or apertures.

Buggy.—A small wagon used for transporting material such as rock. The carriage on which a traveling crane rests.

Timber Buggy.—A compact frame mounted on a single roller, used for transporting heavy sticks of timber.

Build.—The manner of construction. The form of anything. To frame, construct, or erect. The height of a cut masonry stone or its rise, used in contradistinction to its bed, as a "build joint" or a joint in a vertical plane.

Builder's Hoist.—See "Hoist."

Builder's Knot.—See "Knot."

Built Beam.—See "Beam."

Built Channel.—See "Channel."

Built Girder.—See "Girder."

Built Pile.—See "Pile."

Bulb Angle.—See "Angle."

Bulk.—The body of a substance. A painter's term applied to pigment to signify the total volume thereof plus the voids.

Bulkhead.—A partition built in a tunnel or conduit to prevent the passage of air, water, or mud, or in a form for concrete.

Bull-dog.—Calcined tap cinder from puddling furnaces.

Bulldozer.—A machine in which angles are bent in small circular arcs by pressure between two supports.

Bull Gang.—See "Gang."

Bull Press.—Same as "Gag Press." See "Press."

Bull Riveter.—See "Riveter."

Bull Wheel.—See "Wheel."

Bull Wheel Derrick.—See "Derrick."

Bull Wheel Pile Driver.—See "Pile Driver."

Bunker.—A bin used for storing purposes, such as the storing of coal or any other loose material.

Buoy.—A float fixed at a certain place to show the position of any object beneath the water's surface.

Buoyancy.—The upward pressure exerted upon a body by the fluid in which it is immersed. It is equal in amount to the weight of the water displaced.

Centre of Buoyancy.—The centre of gravity of the water displaced by any wholly or partially submerged body.

Buoyant Effort.—Same as "Buoyancy," *q.v.*

Buried Pier.—See "Pier."

Burlap.—A coarse, heavy cloth or mat made from jute, flax, hemp, or manila fibres.

Burning Steel.—See "Steel."

Burnish.—To polish by rubbing; applied chiefly to metals.

Burnt Steel.—See "Steel."

Burr.—A partially vitrified brick; a clinker. A protuberance or raised portion of an object. A nut with a screw-thread. The rough projecting edge of a drilled hole in steelwork.

Riveting Burr.—A washer upon which a rivet-head is swaged down.

Burr Truss.—See "Truss."

Bush.—A perforated box or tube of metal fitted into certain parts of machinery. To dress stone, or the manner of dressing it.

Bushel.—A unit of dry measure containing 2,150.42 cubic inches.

Bush Hammer.—See "Hammer."

Bush-Hammered Dressing.—See "Dressing."

Bushing.—Same as "Bush," *q.v.*

Buster.—A machine for cutting off the heads of rivets; also the edged tool which does the cutting.

Bar Buster.—A rivet cutter on the end of a bar.

Bust Hammer.—See "Hammer."

Butt.—To strike by thrusting; to join at the end. The thick, large, or blunt end of a timber or pile. The square end of a connecting rod.

[illegible]—Same as "Butt," *q.v.*

[illegible]—See "Joint."

Riveting.—See "Riveting."

Splice.—See "Splice."

Strap.—See "Strap."

Weld.—See "Weld."

n Head.—See "Head."

n-headed Spike.—See "Spike."

n Set.—See "Set."

ess.—A short cross-wall built against the main wall to increase its stability.

ing Buttress.—A support in the form of a segment of an arch springing from a solid mass of masonry.

Gang.—See "Gang."

Saw.—See "Saw."

ass.—An extra pipe passing around a valve or chamber to equalize pressure or to prevent a complete stoppage of the flow of the fluid.

product.—A secondary or additional product from any manufacturing process.

wash.—A channel cut to convey the surplus water from a reservoir or aqueduct, for the purpose of preventing overflow.

C

ble.—A heavy rope, chain, or twisted wire rope. An aerial or underground conductor of electricity with insulating covering. The suspending portions of a suspension bridge.

ain Cable.—A very heavy linked chain used in place of a steel wire cable in bridge-work.

rm Cable.—An extra strong cable used to give additional strength or anchorage during severe wind-storms.

spender Cable.—A hanger cable in a suspension bridge for supporting the floor system.

Suspension Cable.—One of the cables forming the support of the floor of a suspension bridge.

Wire Cable.—A cable of heavy wire, or of numerous small wires twisted together.

le Clamp.—See "Clamp."

le Clip.—See "Clip."

le Hoist.—See "Hoist."

Splice.—See "Splice."

le-way.—An underground passage carrying a cable or cables.

ge.—A framework to confine a ball valve within a certain range of motion. A wire guard placed in front of a suction opening to allow liquids to enter, but to prevent the passage of solids of objectionable size. A skeleton framework of any kind surrounding any object.

sson.—A sunken panel in a coffered ceiling. A watertight box or casing used in founding and building structures in water too deep for cofferdams.

Open Caisson.—A crib and cofferdam open to the air and sunk by dredging within the crib.

eumatic Caisson.—A bottomless box or caisson, surmounted by a crib or shaft, into which air is pumped so as to drive out the water and thus permit workmen to enter for the purpose of excavating the bottom and sinking the mass to the required depth.

[illegible]—Same as "Bends," *q.v.*

Horsepower.—Same as "Commercial Horsepower." See "Horsepower."

[illegible]—See "Paper."

[illegible]

Caliper [illegible].—A caliper [illegible]

Caliper [illegible].—A tool [illegible]

Caliper Rule.—An outside caliper [illegible] end.

Caliper Square.—A rule carrying two [illegible] by a nut, the other being [illegible]

Calk, or Caulk.—To drive oakum [illegible] barges, caissons, etc., in order to keep [illegible] leaking.

Calked Rivet.—See "Rivet."

Calking-butt.—An open-end joint between planks [illegible]

Calking-iron.—A dull chisel for calking [illegible]

Calking Mallet.—See "Mallet."

Calking Metal.—See "Metal."

Calking Nail.—See "Nail."

Calking Tool.—See "Tool."

Calyx Core Drill.—See "Drill."

Cam.—An eccentric; a piece fixed upon a revolving [illegible] duce a reciprocating motion in a member [illegible] wiper.

Heart Cam.—A form of cam-wheel used for conver[illegible] uniform reciprocating motion.

Camb.—Same as "Cam," *q.v.*

Camber.—The upward curvature of a span above its [illegible]

Camber Blocks.—See "Blocks."

Cambering Machine.—A machine used for bending [illegible]

Camber Jack.—See "Jack."

Camber-slip.—A slightly curved guide and support of [illegible] straight arches of brick.

Camel-back Top Chord.—See "Chord."

Camel-back Truss.—See "Truss."

Cam Shaft.—See "Shaft."

Canal.—An artificial waterway for navigation. A duct [illegible]

Cancellation.—A system or arrangement of the web [illegible]

Double Cancellation.—The arrangement of the web [illegible] complete systems of diagonals.

Multiple Cancellation.—The arrangement of the web [illegible] more than two complete systems of diagonals.

Single Cancellation.—The arrangement of the web [illegible] one complete system of diagonals.

Triple Cancellation.—The arrangement of the web [illegible] separate systems of diagonals.

Candle-power.—The standard unit of luminous inten[illegible] burning of a standard spermaceti candle at the [illegible] grains per hour.

[illegible]

[illegible] over anything. The hook on a cant-hook for [illegible]

at an angle; to tilt from a horizontal line.

Dog.—Same as "Cant Hook." See "Hook."

Hook.—See "Hook."

tilever.—A bracket of stone, metal, or wood projecting from a [illegible] or wall. Also see Cantilever Bridge, under "Bridges."

Deck Cantilever.—A cantilever bridge in which the traffic is borne by a floor system supported by the top chords or the upper portion of the posts.

Through Cantilever.—A cantilever bridge in which the traffic passes between the trusses, in contra-distinction to a deck cantilever where it passes above the top chords.

tilever-arch Truss.—See "Truss."

tilever-arm.—The projecting arm in a cantilever bridge.

tilever Beam.—See "Beam."

tilever Bracket.—See "Bracket."

tilever Bridge.—See "Bridge."

tilever Crane.—See "Crane."

tilever Truss.—See "Truss."

vas Hose.—See "Hose."

p.—A covering of metal or of tarred canvas at the end of a rope to prevent fraying. The upper part of a journal box. The terminal section of a pipe having a plug at the end. A horizontal timber beam resting on and joining the heads of a row of piles or timbers. The top of a column. The part connecting a pump-rod with the working beam. Also a container for an explosive used in blasting. To cap or to cover.

Double Cap.—A cap set vertically on the top of another.

False Cap.—A cap on a column below the true cap. Also a construction to make an intermediate portion of a structure look like the top.

Falsework Cap.—Any cap used in falsework.

Hand-rail Cap.—The upper horizontal member or members of a hand-rail.

Pedestal Cap.—A block of stone or concrete placed on top of a footing to carry a loaded column.

Percussion Cap.—A small copper cap, or cup, containing fulminating powder which explodes when struck a sharp blow.

Pile Cap.—An iron casting shaped to fit over the head of a pile, and having a conical recess on top to carry a tough wooden block which receives the blows of the hammer. Jaws are provided on the sides of the cap to engage the leads. The function of the cap is to distribute the blow of the hammer and to prevent the brooming of the pile head. Also a timber cap across a row of piles.

Trestle Cap.—The upper horizontal beam in the timber framing supporting the deck of a trestle bridge.

Chisel.—See "Chisel."

tal.—The upper part of a column, pilaster, or pier. The money value set on the property or assets involved in a business enterprise.

alized Cost.—See "Cost."

alized Value.—Same as "Present Worth," *q.v.*

[illegible]—A rectangular timber covering the top of a row of squared timber posts.

[illegible]—A general term for a series of caps in a structure. Putting a timber cap [illegible] row of piles.

[illegible]—See "Plate."

[illegible]—See "Screw."

[illegible] Sill."

[illegible]

Barrel of a Capstan.—That part of

Chinese Capstan.—A differential
or hauling.

Differential Capstan.—A capstan operated by

Pawls of a Capstan.—The stops on the
motion.

Power Capstan.—A capstan in which
reduce the speed.

Capstan Bar.—One of the levers by which a capstan

Capstan Head.—See "Head."

Capstone.—The uppermost or finishing stone of a

Car.—A conveyance or receptacle running upon

Derrick Car.—A railroad car upon which a derrick

Dump Car.—A truck car having a body pivoted
when emptying.

Erection Car.—A car specially fitted with a derrick
erection of bridges.

Hand Car.—A small flat-car mounted on four
and operated by handpower, used for carrying
repairs.

Locomotive Car.—A locomotive and railroad carriage

Pneumatic Car.—A car running on rails and driven by

Carbon Steel.—See "Steel."

Carborundum.—A combination of silica and carbon
in place of emery as an abrasive material.

Carborundum Brick.—See "Brick."

Carpenter's Level.—See "Level."

Carpenter's Line.—See "Line."

Carriage.—Any part of a machine that carries another
frame which supports the steps of a wooden stair.

Wheel Carriage.—The frame or box holding the bearing

Carrick Bend Knot.—See "Knot."

Case-hardened Steel.—See "Steel."

Case-hardening.—Converting the outer surface of iron
in contact with charcoal.

Case Steel.—See "Steel."

Casing.—A wooden tunnel for the powder-hose in blasting
is used in making borings. A covering.

Boring Casing.—A wrought-iron pipe from 2½ inches
placed outside of the churn pipe, used in drilling test

Timber Casing.—Timber sheathing used on the outside

Cast.—To make a casting out of molten metal. A small
a mould for casting pipes.

Caster Wheel.—See "Wheel."

Cast Gear.—See "Gear."

Casting.—The act or process of founding. That which has
metal into a mould.

Base Casting.—A steel or iron casting upon which the

Centering Casting.—A casting used to bring a movable
when seated.

Chair Casting.—A casting used to support the end of a

Chilled Castings.—Castings which are rapidly cooled

Cast Iron.—See "Iron."

Malleable Cast "Iron."—See "Iron."

Cast-iron Pipe.—See "Pipe."

Cast Steel.—See "Steel."

Crucible Cast Steel.—See "Steel."

Catch.—Any mechanical contrivance used for stopping, checking, or preventing motion.

Catch-basin.—A reservoir placed at the outer end of a sewer connection to intercept the flow of water in a gutter.

Catch-drain.—Same as "Catch-water," *q.v.*

Catchment Area.—Same as "Drainage Area," *q.v.*

Catch-water.—A channel or drain running along sloping ground or pavement to catch and carry away the water.

Catch-work.—Same as "catch-water," *q.v.*

Catenary.—A curve formed by a flexible, inextensible cord or chain of uniform weight per unit of length, hung at two points and supporting its own weight alone.

Inverted Catenary.—A curve formed by reversing the position of an ordinary catenary so as to make it convex upward.

Transformed Catenary.—A curve formed by an increasing or decreasing of all the ordinates of a common catenary according to a given ratio.

Catenary Arch.—See "Arch."

Cat's-paw Knot.—See "Knot."

Cattle Guard.—See "Guard."

Causeway.—A raised footway or road.

Caustic Lime.—See "Lime."

Cedar Block.—See "Block."

Cell.—A unit of an electric battery consisting of two plates of different substances, usually zinc and carbon, immersed in an exciting liquid held in a jar, so as to set up an electric current.

Cement.—Any composition which at one temperature or one degree of moisture is plastic, and at another condition of temperature or moisture is tenacious. A mortar which hardens. To unite by cement.

Activity of Cement.—The time required for a cement to pass from its initial set to its final or hard set as determined by the Vicat Needle.

Bituminous Cement.—A cement or mastic in which bitumen, usually in the form of asphalt, is the chief ingredient.

Boiling Test of Cement.—See "Boiling Test."

Dry Process in Cement Manufacture.—The process of making Portland cement by mixing the ingredients dry and then burning them into a clinker.

Final Set of Cement.—See "Set."

Grappiers Cement.—A cement made in France from particles which have escaped disintegration in the manufacture of hydraulic lime.

Hard Set of Cement.—Same as "Final Set." See "Set."

Hydraulic Cement.—A cement which sets or hardens under water. There are three common kinds: Portland, natural, and Pozzuolana.

Initial Set of Cement.—See "Set."

Laitance of Cement.—That portion of a hydraulic cement which escapes from concrete that is placed under water and which floats on the surface. It is injurious to concrete, and should be removed. Its formation in large quantities indicates a defect in the method of depositing the concrete.

Liatier Cement.—Same as "Slag Cement," *q.v.*

Natural Cement.—Formerly a pulverized stone which, without having heat applied, acquired the property of hardening under water. The term is now applied to a cement made from natural rock (containing the required constituents in approximately uniform proportions) by calcining and grinding.

[illegible]

[illegible] **Cement.**—A [illegible] [illegible]. The name is derived [illegible] [illegible]. In this country [illegible] [illegible] the product is called [illegible]

Quick-setting Cement.—A cement that sets [illegible] after mixing.

Roman Cement.—A natural [illegible] dale, supposed to have been used by the [illegible]

Rosendale Cement.—A hydraulic, natural [illegible] has an ultimate tensile strength of about [illegible] comes from Rosendale, N. Y. The term [illegible] for natural cement.

Rust Cement.—Iron turnings treated with acid and [illegible] permissible in good engineering practice.

Sand Cement.—A mechanical mixture of Portland [illegible] so as to produce a very fine powder. [illegible] not as strong as good Portland cement.

Silica Cement.—Same as "Sand Cement," *q.v.*

Slag Cement.—Same as "Pozzuolana Cement," [illegible]

Slapped Cement.—Cement mortar thrown against [illegible] casting a house.

Slow-setting Cement.—A cement that sets in from [illegible]

Soundness of Cement.—A term denoting freedom [illegible] cracking, or checking in setting of cement.

Wet Process.—A method in the manufacture of [illegible] are mixed together with an ample amount of water [illegible] and ground.

Cementation.—The process of converting wrought-iron [illegible] tact with charcoal. The act of cementing; the act of [illegible]

Cement Bin.—See "Bin."

Cement Brick.—See "Brick."

Cement Briquette.—See "Briquette."

Cemented Steel.—See "Steel."

Cement Finish.—See "Finish."

Cement Floor.—See "Floor."

Cement Gun.—See "Gun."

Cementing Furnace.—See "Furnace."

Cement Kiln.—See "Kiln."

Cement Mill.—See "Mill."

Cement Mortar.—See "Mortar."

Cement Mould.—See "Mould."

Cement Needle.—See "Needle."

Cement Pile.—Same as "Concrete Pile." See "Pile."

Cement Stone.—See "Stone."

Cement Testing Machine.—An apparatus for testing the [illegible] for determining the tensile strength, but occasionally [illegible] compression.

Centering.—See "Arch Centre."

Centering Casting.—See "Casting."

Centre.—The middle or reference point of an object.

Meta-centre.—See "Meta-centre."

Centre Bearing.—See "Bearing."

Centre-bearing Draw.—See "Draw."

Centre-bearing Turntable.—See "Turntable."

Centre Drill.—See "Drill."

Centre Line.—See "Line."

Centre of Buoyancy.—See "Buoyancy."

Centre of Displacement.—Same as "Centre of Buoyancy," *q.v.*

Centre of Gravity.—See "Gravity."

Centre of Gyration.—See "Gyration."

Centre of Inertia.—See "Inertia."

Centre of Magnitude.—That point in a body which is equally distant from all the similar external parts of it.

Centre of Mass.—See "Mass."

Centre of Moments.—See "Moments."

Centre of Motion.—Same as "Centre of Rotation," *q.v.*

Centre of Percussion.—See "Percussion."

Centre of Perspective.—See "Perspective."

Centre of Pressure.—See "Pressure."

Centre of Resistance.—See "Resistance.

Centre of Rotation.—See "Rotation."

Centre of Stress.—See "Stress."

Centre of Symmetry.—See "Symmetry."

Centre Pin.—See "Pin."

Centre Punch.—See "Punch."

Centre Valve.—See "Valve."

Centrifugal Force.—See "Force."

Centrifugal Load.—See "Load."

Centrifugal Pump.—See "Pump.'

Centrifugal Stress.—See "Stress.

Centripetal Force.—See "Force."

Centripetal Stress.—See "Stress."

Centroid.—The centre of mass, or centre of gravity. The point of application of the resultant of a system of stresses or forces.

Chain.—A connected series of links of metal serving the purpose of a band, cord, rope, cable, or measuring line. To tie or fasten with a chain.

Bent-linked Chain.—A coil chain in which the links are bit or bent.

Coil Chain.—A straight-linked chain, in which the links are in the shape of two letters U joined at their tops.

Curb Chain.—Any chain used as a check upon the motion of any moving piece or apparatus.

Endless Chain.—Any chain in the form of a loop without an end.

Hog Chain.—A chain cable or rod stretched over the straining posts in a Hog-chain Truss. See "Truss." Same as the rod used for trussing a beam.

Hook and Ring Chain.—A chain with a hook at one end and a ring at the other. Called also a "Sling Chain."

Hook Chain.—A chain having a hook on one end or one at each end.

Jack Chain.—A small chain each link of which is formed of a single piece of wire bent into two loops resembling the figure eight.

Jet Chain.—The chain which picks up a pipe that is used for the purpose of jetting.

Kibble Chain.—The chain which draws up the kibble or bucket from the hole.

Link Chain.—A chain made of links.

Machine Chain.—A chain with

Ring Chain.—A chain having rings at the

Roller and Thimble Chain.—A chain in which
rollers and thimbles.

Sling Chain.—Same as "Hook and Ring Chain

Stayed Link Chain.—A coil chain in which all the
a "Stud Link Chain."

Stud Link Chain.—Same as "Stayed Link Chain

Wheel Chain.—A chain constructed so as to

Chain Bearer.—That one of the staff in a survey
engineer's or surveyor's chain or tape. The

Chain Blocks.—An endless chain running over two
hoisting.

Chain Bond.—See "Bond."

Chain Bridge.—See "Bridge."

Chain Cable.—See "Cable."

Chain Casting.—See "Casting."

Chain Coupling.—See "Coupling."

Chain Dog.—See "Dog."

Chain Drive.—A mechanism consisting of a chain or

Chain Gear.—See "Gear."

Chain Hoist.—See "Hoist."

Chain Hook.—See "Hook."

Chain Knot with a Toggle.—See "Knot."

Chainman.—Same as "Chain Bearer," *q.v.*

Chain Pulley.—Same as "Chain Wheel," *q.v.*

Chain Pump.—See "Pump."

Chain Riveting.—See "Riveting."

Chain-smith.—One who makes chains.

Chain Tape.—See "Tape."

Chain Wheel.—See "Wheel."

Chalk Line.—See "Line."

Chamber.—The recess in an axle box designed to hold the
or an enclosed space, as the chamber in a caisson.

Air Chamber.—An enclosed space containing air. In
to the working chamber in a pneumatic caisson.

Air Working Chamber.—A chamber in a caisson into which
to expel the water so that laborers can work at

Working Chamber.—Same as "Air Working Chamber,"

Chamfer.—To bevel or sharpen to a blunt edge.

Chamfered Joint.—See "Joint."

Channel.—The deepest part of a river, bay, or stream;
navigation. The trough used to conduct molten
moulds. To form or cut a channel. A structural
bridge building and in other steel constructions.

Built Channel.—A shape in the form of a channel
angle irons.

Rolled Channel.—A channel which is rolled in one piece,
built channel.

Channel Column.—See "Column."

Channeling.—Making a new channel. Grooving or
system of channels or gutters.

neling-machine.—A machine for cutting grooves or channels when quarrying stone.

annel Iron.—Same as "Rolled Channel," *q.v.*

annel Span.—See "Span."

annel Strut.—See "Strut."

aracteristic Curve.—See "Curve."

arcoal Iron.—See "Iron."

arcoal Steel.—See "Steel."

arred Piles.—See "Pile."

ats.—Tailings from mills in which zinc and lead ores are treated.

eck.—A small crack in wood due to seasoning, or in concrete or mortar due to drying.

Heart Check.—A check in the heart of a timber.

ck Nut.—See "Nut."

eck Valve.—See "Valve."

eck Washer.—See "Washer."

enoweth Pile.—See "Pile."

illed Casting.—See "Casting."

illed Iron.—See "Iron."

inese Anchor.—See "Anchor."

inese Capstan.—See "Capstan."

inese Windlass.—See "Windlass."

ipping Hammer.—See "Hammer."

isel.—A hard tool consisting of a sharp-ended blade designed to cut under the impulse of a blow.

Cape Chisel.—A hand tool made from a short steel bar having one end flat and the other tapering to a blunt edge sharpened at an obtuse angle to prevent breaking. Used in connection with a hand hammer for chipping cast iron. It differs from a cold chisel in having a narrower blade with more stock behind it.

Cold Chisel.—A hand tool made from a short steel bar having a flat top and a tapering wedge-shaped end a trifle wider than the shank. Used for cutting metals while cold.

Framing Chisel.—A heavy carpenter's chisel, used in mortising timbers.

Heading Chisel.—A mortise chisel.

Hot Chisel.—A chisel used for cutting metals while hot.

Pitching Chisel.—A stone mason's chisel for making a well-defined edge to the face of a stone block.

gging Chisel.—A heavy chisel used for cutting off bolt heads.

litting Chisel.—A wedged-shaped chisel.

oth Chisel.—Same as "Pitching Chisel," *q.v.*

isel Bar.—See "Bar."

isel Draft.—See "Draft."

iseled Dressing.—See "Dressing."

ock.—A block, a piece of wood, or other material specially prepared and generally wedge-shaped, used to prevent movement by insertion under wheels, etc. To secure by putting a chock into or under a moving object, or one that is likely to move.

ock-a-block.—Jammed. Said of a tackle when the blocks are so close hauled as to prevent further motion.

ck Block.—See "Block."

ord.—That portion of a truss the main function of which is to resist bending on the span.

Chord.—The lower member of a truss, usually resisting tension.

Chord.—A top chord in which each successive segment deviates or deflects line of its contiguous segment, at the panel point.

[illegible]

[illegible] Chord.—Same as "[illegible]

[illegible] Chord.—A chord of a [illegible]

Polygonal Top Chord.—A top chord [illegible] a polygon.

Top Chord.—The upper member of a [illegible]

Upper Chord.—Same as "Top Chord." [illegible]

Windward Chord.—The chord of a span on [illegible] the wind comes).

Chord Bar.—See "Bar."

Chord Boring-machine.—See "Boring-machine."

Chord Head.—See "Head."

Chord Packing.—See "Packing."

Chord Pin.—See "Pin."

Chord Pitch.—See "Pitch."

Chord Splice.—See "Splice."

Chord Stress.—See "Stress."

Chord Stringer.—See "Stringer."

Chrome Steel.—See "Steel."

Chuck.—A device attached to a revolving [illegible] object to be turned.

Drill Chuck.—A type of chuck which holds a drill [illegible]

Churn Drill.—See "Drill."

Chute.—An inclined trough or pipe along which [illegible] to a lower level. Also spelled "Shoot."

Cincture.—A ring, list, or fillet at the ends of a column [illegible] from the capital or the base.

Cinder.—Slag, especially that produced from [illegible] Ordinarily the residue of burnt coal, being the [illegible] to form lumps.

Puddle Cinder.—Cinder removed from the molten metal [illegible] the impurities has been completed.

Cinder Concrete.—See "Concrete."

Cinder Pig.—See "Pig."

Cinder Pocket.—See "Pocket."

Cinematics.—Same as "Kinematics," *q.v.*

Circle.—A graduated plate on a transit.

Circuit.—The arrangement by which an electrical current [illegible] two poles of a generator or battery.

Circuit-breaker.—A device for automatically opening an [illegible]

Circular Arch.—See "Arch."

Circular File.—See "File."

Circular Girder.—See "Girder."

Circular Pitch.—See "Pitch."

Circular Saw.—See "Saw."

Clack Valve.—See "Valve."

Clamp.—An instrument or tool consisting of two movable [illegible] gether by a screw or other suitable mechanism, used [illegible] by pressure. One of a pair of movable cheeks on [illegible]

Cable Clamp.—A clamp consisting of a U bolt, saddle, and two nuts, used on cables.

Fitting-up Clamp.—An ordinary screw clamp, used for fitting up instead of bolts.

Pipe Clamp.—A vise for holding pipes.

Rail Clamp.—A wedge used for tightening a rail in a rail chair.

Rope Clamp.—A device consisting of a pair of clamping jaws carrying a ring and hook used for securing or attaching the end of a rope to some object.

Screw Clamp.—A clamping device operated by a screw.

Clamp Drill.—See "Drill."

Clamp Iron.—Same as "Clamp," *q.v.*

Clamp Screw.—A clamp operated by a thumb-screw.

Clam-shell Bucket.—See "Bucket."

Clam-shell Dredge.—See "Dredge."

Clap-boards.—Short, thin boards, shingle shaped, and used instead of shingles.

Clapper Valve.—See "Valve."

Classification.—The distribution into sets, sorts, or ranks.

Classify.—To arrange in classes, sorts, or ranks according to some method founded on common characteristics in the objects so arranged.

Claw.—A split provided at the end of a bar or a hammer for taking hold of the heads of nails, spikes, or bolts so as to withdraw them from wood.

Clawback.—A balk or a beam, used in making floating bridges.

Claw Bar.—See "Bar."

Claw Coupling.—See "Coupling."

Claw Hammer.—See "Hammer."

Claw Wrench.—See "Wrench."

Clay-daubed.—Cracks filled with clay, as is sometimes done in forms for concrete.

Clay Puddle.—See "Puddle."

Clearance.—The space allowed for the passage of any vehicle or craft through or near a construction. The additional space allowed for the fitting together of members over that nominally required, in order to provide for slight irregularities of workmanship or materials.

Horizontal Clearance or Lateral Clearance.—The horizontal space allowed for the passage of any vehicle or craft through or near a construction.

Vertical Clearance.—The vertical or overhead space allowed for the passage of any vehicle or craft, measured above the roadway or the water level.

Clearance Diagram.—See "Diagram."

Clearance Line.—See "Line."

Clear-headway.—The vertical distance from the upper surface of a floor to the lowest part of the overhead bracing. It is the measure of height of the tallest vehicle that could pass through the bridge. Also the vertical distance from the water surface or the ground to the lowest part of the superstructure.

Clear Roadway.—See "Roadway."

Clear Span.—See "Span."

Clear Waterway.—See "Waterway."

Cleat.—A piece of wood or iron with projecting prongs, used for belaying or winding ropes on so as to make them fast.

Cleave.—To part or divide by force. To rend asunder, as to cleave wood or rock.

Cleveland Hammer.—See "Hammer."

Clevis.—A connecting iron bent into the form of a horseshoe, stirrup, or letter U. Also a link in a chain shaped like the letter U. An adjusting piece for bridge members of varying length.

Clevis Pin.—See "Pin."

Click.—Same as "Ratchet," *q.v.*

[illegible].—A hold-fast. To [illegible] attachment. To [illegible]

Clinch Bolt.—See "Bolt."

Clinker Brick.—See "Brick."

Clinton Wire Cloth.—A form of wire netting the longitudinal wires heavier than the

Clip.—A fastening. The hinged yoke on

Angle Clip.—Same as "Clip Angle." See

Briquette Clips.—The clips or jaws on a briquette while being stressed.

Cable Clips.—A device for hanging an electric attaching anything to a cable.

Pulley Clip.—A clip attached to a pulley to from slipping.

Spring Clip.—A clip worked by a spring for holding

Clip Pulley.—See "Pulley."

Closed Column.—See "Column."

Close-quartered Reamer.—See "Reamer."

Closing Line.—See "Line."

Closing Pile.—See "Pile."

Clove-hitch.—See "Knot."

Club Dolly.—See "Dolly."

Cluster Bent.—See "Bent."

Clutch.—A movable coupling or locking or unlocking motion.

Coil Friction Clutch.—A friction clutch composed of a iron drum.

Cone Clutch.—A clutch consisting of conical plug, a hollow drum shaped to receive the plug that

Friction Clutch.—A device for conveying motion from by the frictional resistance between plates in contact,

Jaw Clutch.—A clutch composed of two hub-like each other. One hub is arranged to slide on its so that it can be thrown in or out of gear.

Pulley Clutch.—An automatic device in the form of a a hoisting pulley to a beam.

Clutch Coupling.—See "Coupling."

Coarse Sand.—See "Sand."

Cobblestone.—A stone used in pavements, usually rounded

Cock.—A faucet or turn valve consisting of a tapering through it for the passage of fluids. This plug fits a corresponding taper, so that in one position the another position it is opened.

Pet Cock.—A small cock used for draining pipes, etc.

Plug Cock.—A cock or a faucet which has a tapered fitting into a prepared seat in a pipe.

Cocked-hat.—A coping projecting from the shaft of a pier water, used for enlarging the lower portion of the creasing the stability and reducing the foundation

Coefficient.—A constant factor in an algebraic expression.

Differential Coefficient.—The measure of the rate of to its variable. A term used in the calculus.

Empirical Coefficient.—A coefficient established by than by scientific deduction from fundamental

Coefficient of Contraction.—See "Contraction."

Coefficient of Elasticity.—See "Elasticity."

Coefficient of Expansion.—See "Expansion."

Coefficient of Friction.—See "Friction."

Coefficient of Impact.—See "Impact."

Coefficient of Lineal Expansion—See "Expansion."

Coefficient of Resilience.—See "Resilience."

Coefficient of Restitution.—See "Restitution."

Coefficient of Torsion.—See "Torsion."

Cofferdam.—A temporary enclosing structure, practically watertight, from which the water is pumped, and within which masonry or concrete is placed in the open air.

Movable Cofferdam.—A cofferdam constructed of timber, hinged at one corner and joined on the diagonal corner in such a way that it can be opened, after the pier is built, and moved away to another pier site.

Cog.—A tooth, catch, or projection on the periphery of a wheel.

Cog Wheel.—Same as "Gear," *q.v.*

Cohesion.—The force that holds together the individual particles of a body.

Coignet, Beton.—See "Beton-Coignet."

Coil Chain.—See "Chain."

Coil Friction Clutch.—See "Clutch."

Cold Chisel.—See "Chisel."

Cold-cut or Cold Cutter.—A cold chisel mounted on a handle like a hammer. It is used with the application of a maul.

Cold-hammering.—The act or practice of hammering metal when cold.

Cold-pressed.—Pressed when cold. Applied generally to iron or steel.

Cold-pressed Paper.—See "Paper."

Cold-rolled.—Rolled when cold. Applied generally to iron or steel.

Cold-rolled Shafting.—See "Shafting."

Cold Saw.—See "Saw."

Cold-short.—The condition of brittleness in steel when it is cold; caused by excessive phosphorus.

Cold-short Iron.—See "Iron."

Cold-short Steel.—See "Steel."

Cold Shut.—See "Shut."

Cold-straightening.—The process of straightening metal when cold.

Collapsing Bucket.—See "Bucket."

Collar.—A flat ring surrounding anything closely.

Thrust Collar.—A collar on a shaft set to resist end thrust.

Collar Beam.—See "Beam."

Collision Post.—Same as "Collision Strut." See "Strut."

Collision Strut.—See "Strut."

Color.—A generic term referring inclusively to all of the colors of the spectrum, white and black, and all tints, shades, and hues which may be produced by their admixture.

Column.—A pillar or strut. A long member which resists compression.

Bethlehem Column.—A wide "H" column rolled in a four-roll mill by the Bethlehem Steel Company, similar to that of the "Bethlehem Beam," *q.v.*

Box Column.—A column made in the shape of a box, having sides of steel plates united by angles.

Channel Column.—A column made up of two channel-irons laced or stayed.

Closed Column.—A column that is boxed in, shutting out water and air, generally rendering the interior inaccessible for painting.

[illegible]

[illegible]

[illegible]

[illegible] Column.—A [illegible] with thimbles or [illegible]

Long Column.—A column which will [illegible]

[illegible] Column.—Same as the [illegible]

[illegible]

Phoenix Column.—A fabricated column [illegible] together forming a circular section [illegible] through which the rivets pass.

Pin-end Column.—A column that is free [illegible]

Short Column.—A column which will fail by [illegible]

Spandrel Column.—A column resting on the [illegible] the roadway above.

Square-end Column.—A column bearing on [illegible]

Z-Bar Column.—A fabricated column composed of [illegible] riveted together.

Columnar Fracture.—See "Fracture."

Columnar Pile.—See "Pile."

Column Bent.—See "Bent."

Column Crane.—See "Crane."

Column-foot.—The base of a column.

Column Footing.—See "Footing."

Combination Bridge.—See "Bridge."

Combination Dolly.—See "Dolly."

Combination Punch and Shears.—An apparatus [illegible] shearing.

Combination Wrench.—See "Wrench."

Combined Bridge.—See "Bridge."

Combined Stress.—See "Stress."

Commercial Horsepower.—See "Horsepower."

Common Iron.—See "Iron."

Common Lime.—See "Lime."

Common Logarithm.—See "Logarithm."

Common Reamer.—See "Reamer."

Compass.—An instrument used to indicate the [illegible] tion of an object with reference to that meridian. [illegible] circles.

Beam Compass.—A bar having two slides mounted [illegible] point or centre, and the other the marking-pencil [illegible] circles.

Compensator.—An equalizing device on machines or engines.

Component.—A constituent part. One of the parts into [illegible] be resolved or divided.

Horizontal Component.—A component of an oblique [illegible]

Longitudinal Component.—A component in a direction [illegible] trusses.

Transverse Component.—A component in a transverse [illegible] for a component perpendicular to the planes of the [illegible]

Compound Curve.—See "Curve."

Compound Girder.—See "Girder."

Compound Locomotive.—See "Locomotive."

Compound Pulley.—See "Pulley."

Compound Stress.—See "Stress."

Compound Web Plate.—See "Plate."

Compression.—The state of being compressed; shortening by pressure.

Compression Joint.—See "Joint."

Compressive Strain.—See "Strain."

Compressive Strength.—See "Strength."

Compressive Stress.—See "Stress."

Compressor.—An apparatus for compressing liquids or gases.

- **Air Compressor.**—A machine by which air is compressed into a receiver so that its expansion may be utilised as a source of power.

Computations.—Calculations; the figuring of bridgework.

Concave Brick.—See "Brick."

Concave Curvature.—See "Curvature."

Concentrated Load.—See "Load."

Concentrated Load Stress.—See "Stress."

Concentration.—A system of loading in which several loads are collected and applied at a point or over a very small area.

- **Axle Concentration.**—The load from one axle of a locomotive or vehicle concentrated on a structure, or twice a wheel load.
- **Double Concentration.**—A term descriptive of the method of figuring stresses in bridges for a live load, consisting of a string of cars of uniform weight per lineal foot headed by an excess load equal to the difference between the total weight of an engine and tender and the product of the length of the two by the weight per lineal foot of the cars, and followed by another similar and equal excess load two panel lengths (about fifty feet) back of the head of the train. This type of live load is no longer used, as it has been replaced by the "equivalent uniform live load."
- **Floor-beam Concentration.**—The load transferred from one line of stringers to a floor-beam.
- **Single Concentration.**—Similar to Double Concentration (*q.v.*) except that the second excess load is omitted. It, too, is no longer used.
- **Wheel Concentration.**—The amount of load carried and delivered by one wheel.

Conchoidal Fracture.—See "Fracture."

Concrete.—An artificial stone made by mixing some cementing material with an aggregate composed of hard, inert particles of varying size. Usually the cementing material is Portland cement, and the hard, inert particles are sand and broken stone, water being added to make the cement active.

- **Bituminous Concrete.**—A concrete composed of bitumen, sand, and broken stone.
- **Broken Stone Concrete.**—A concrete composed of cement, sand, broken stone, and water.
- **Cinder Concrete.**—A concrete composed of cement, sand, cinders, and water.
- **Cyclopean Concrete.**—Concrete in which large stones or boulders, sometimes called plums, have been bedded.
- **Gravel Concrete.**—A concrete composed of cement, sand, gravel, and water.
- **Green Concrete.**—Concrete that is fresh or has not yet gained its full strength.
- **Lead Slag Concrete.**—A concrete made with lead slag in place of the usual broken stone.
- **Portland Cement Concrete.**—Concrete in which Portland cement is used with water as the cementing material.
- **Reinforced Concrete.**—Concrete in which steel bars are inserted to strengthen it, principally by resisting the tensile stresses induced by external forces.

Concrete.

Slag Concrete.—A concrete composed

blast furnace.

Concrete Batch Mixer.—See "Mixer."

Concrete Continuous Mixer.—See "Mixer."

Concrete Floor.—See "Floor."

Concrete Girder.—See "Girder."

Concrete Masonry.—See "Masonry."

Concrete Mixer.—See "Mixer."

Concrete Pier.—See "Pier."

Concreting.—The act of mixing and placing concrete.

Concurrent Forces.—See "Force."

Condenser.—An apparatus for reducing gases or

Ejector Condenser.—A form of condenser operated

engine cylinder.

Hydraulic Condenser.—A chamber in which gas

Injection Condenser, or Jet Condenser, or Siphon

in which the injected water comes in contact with

Steam Condenser.—A condenser used for steam.

Conduit.—An underground, narrow passage.

A pipe, tube, or underground passage carrying

Cone Clutch.—See "Clutch."

Cone Pulley.—See "Pulley."

Conical Gears.—See "Gears."

Conical Pulley.—See "Pulley."

Conical Roller.—See "Roller."

Conical Wheel.—See "Wheel."

Conjugate Stresses.—See "Stress."

Connecting Angle.—See "Angle."

Connecting Bar.—See "Bar."

Connecting Chord-heads.—Chord-heads used to connect

to pins.

Connecting Plate.—See "Plate."

Connecting Rod.—See "Rod."

Conservation of Energy.—See "Energy."

Consolidation Locomotive.—See "Locomotive."

Construction Bolt.—See "Bolt."

Continuous Beam.—See "Beam."

Continuous Girder.—See "Girder."

Continuous Span.—See "Span."

Continuous Stringers.—See "Stringers."

Continuous Truss.—See "Truss."

Contour Line.—See "Line."

Contour Map.—Same as "Topographic Map." See "Map."

Contract.—An agreement between two or more parties

definite thing.

Sub-Contract.—A contract which has been sublet.

Contraction.—The act of drawing together or shrinking.

or volume of anything.

Coefficient of Contraction.—The ratio between the

section, or volume and the original length, area

temperature change, it is the same as the "Coeffic

hydraulics, it is the ratio between the area of the

issuing from an orifice and the area of the orifice.

Contraction.

Lateral Contraction.—A lateral shrinking or shortening.

Contractor.—One who contracts or covenants either with the government or other public bodies, or with private parties to furnish supplies, or to construct works, or to perform any work or service at a certain price or rate.

General Contractor.—A principal contractor who sublets the whole or part of the whole contract.

Sub-Contractor.—One who takes a part or the whole of a contract from the principal contractor.

Contraflexure.—A reversal of bending in a column or beam.

Converted Iron.—See "Iron."

Converted Steel.—See "Steel."

Converter.—Same as "Bessemer Furnace." See "Furnace."

Convex Curvature.—See "Curvature."

Conveyor.—An apparatus or machine which carries material from one point to another.

Coordinate Paper.—See "Paper."

Coordinates.—A system of lines or angles, or both, by means of which the position of a point is determined by referring to certain fixed lines or points.

Origin of Coordinates.—The initial point in a system of coordinates to which other points are referred. In the rectangular system, it is the intersection of the two axes; in the polar system it is the point in the directrix about which the radius vector turns.

Polar Coordinates.—A system of coordinates in which the position of any point is defined by an angle and a distance from a fixed line and point.

Rectangular Coordinates.—A system of coordinates in which the position of any point is defined by its distances from two lines, called axes, making right angles with each other; or from three mutually perpendicular planes.

Semi-polar Coordinates.—A system of coordinates in which the radius vector of the polar system is combined with one of the coordinates of the rectangular system.

Cope.—To dress. To put a coping on a pier. To notch steel beams, channels, etc.

Cope Chisel.—Same as "Cape Chisel." See "Chisel."

Coping.—The top or cover of a wall, column, or pier. Usually made so as to project beyond the face below.

Starling Coping.—Same as "Cocked-hat," *q.v.*

Coping-machine.—A machine for notching structural shapes.

Coping Stone.—See "Stone."

Copper.—A reddish ductile metal having a specific gravity of 8.8 and a high conductivity for heat and electricity.

Corbel.—A small shelf cantilevered out from a beam, wall, or column in order to support a beam or a superincumbent load. Sometimes called a tassel or bragger.

Corbel Bolster.—See "Bolster."

Corbel Course.—See "Course."

Core.—To make or to cast a core. The inner part or filling of a wall. The internal mould in a casting.

[illegible] Boring.—See "Boring."

[illegible] Drill.—See "Drill."

[illegible] Bracket.—See "Bracket."

[illegible]—The projection at the top of a wall that is finished by a blocking course.

[illegible]—The disintegration of a substance by the action of chemical agents.

[illegible]—Bent or drawn into parallel furrows or ridges. Wrinkled; fluted.

[illegible] Bar.—See "Bar."

[illegible] Dolly.—See "Dolly."

[illegible]—See "Iron."

[illegible]—See "Pile."

[illegible]

[illegible] Cost.—The sum of all the [illegible] [illegible] and construction of a [illegible]

[illegible] Cost.—All expenditures for [illegible] in operating a structure or plant. [illegible]

Operating Cost.—All expenditures [illegible] not pertaining to upkeep nor to repairs.

Unit Cost.—The cost of a unit quantity of [illegible]

Cotter.—A beveled piece of wood or steel, used [illegible] steel key, used for the same purpose. [illegible]

Cotter Bolt.—Same as "Cotter Pin." See "Pin." [illegible]

Cotter Key.—Same as "Cotter," *q.v.* [illegible]

Cotter Pin.—See "Pin." [illegible]

Counter.—An adjustable diagonal in a truss, not [illegible] partial applications of the live load. [illegible]

Counterbalance.—To weigh against with an [illegible] Sometimes used as a synonym for counterweight, *q.v.* [illegible]

Counterbore.—The reboring of a cylindrical hole [illegible] diameter than the original. [illegible]

Counterbrace.—A web diagonal which transmits [illegible] (in relation to span-length) to that carried by the [illegible]

Counterfort.—A short cross-wall built behind the main [illegible] by acting as an anchor to hold back the main wall. [illegible] of a buttress.

Counterpoise.—Same as "Counterbalance," *q.v.* [illegible]

Counter Shear.—See "Shear." [illegible]

Countersink.—A drill or brace-bit for countersinking. [illegible] a conical cavity in timber, metal, or other material, [illegible] of a bolt, rivet, or screw, so that the end thereof [illegible] of the said material.

Countersink Drill.—See "Drill."

Countersinking Reamer.—See "Reamer.'

Counter Stress.—See "Stress."

Counter Strut.—See "Strut."

Countersunk Bolt.—See "Bolt."

Countersunk Rivet.—See "Rivet."

Counterweight.—A weight that counterbalances some [illegible] against. Similar to "Counterbalance," *q.v.*

Couple.—Two equal and parallel forces acting in opposite [illegible]

Moment of a Couple.—The tendency of a couple to [illegible] the product of one of the two equal forces by the [illegible] them.

Stress Couple.—A pair of equal and opposite stresses [illegible]

Coupling.—The act of uniting and joining. The part that [illegible]

Chain Coupling.—A hook connected to the end of a chain [illegible] it with another chain or object.

Claw Coupling.—A coupling in which the claws of one [illegible] other part with a little amount of play; so that [illegible] the coupling will accommodate itself to the obliquity [illegible]

[illegible]

[illegible] Coupling.—A connection produced by means of a clutch.

[illegible] Coupling.—An extensible coupling designed for varying the speed of the part of the machinery which is driven.

Disk Coupling.—A permanent coupling consisting of two disks keyed on the contiguous ends of two shafts.

Flange Coupling.—A coupling made up of two parts, each firmly attached to the end of its shaft, bolted together to form a permanent connection.

Friction Coupling.—An adjustable connection consisting of a cone keyed rigidly to one shaft against which a movable part, having an interior conical surface, sliding on a feather on the other shaft can be pressed.

Jaw Coupling.—Same as a "Claw Coupling," *q.v.*

Joint Coupling.—A form of universal joint in which the sections are coupled and locked together.

Pipe Coupling.—A threaded sleeve into which are screwed the ends of the two pieces of pipe to be coupled.

Ratchet Coupling.—A shaft coupling consisting of a ratchet-wheel on one shaft turning a similar one on the other shaft.

Shaft Coupling.—Any of the several devices for joining the ends of two shafts.

Sleeve Coupling.—A permanent connection in which the coupling consists of a wide band of metal extending over both ends of the shafts to be joined.

Square Coupling.—A form of coupling box, consisting of two longitudinal halves, having a squared hole to fit the squared ends of the two shafts to be connected.

Coupling Box.—See "Box."

Coupling Link.—A link connecting two objects.

Coupling Pin.—See "Pin."

Coupling Valve.—A coupling having one end threaded to receive a metal pipe and the other with a shank to fit a hose.

Course.—A horizontal layer of stone in a masonry wall, or of a pavement.

Binder Course.—That portion of a pavement connecting the wearing surface to the base.

Corbel Course.—A course of brick or stone projecting from the face of a wall and forming a support for an eccentrically applied load.

Footing Course.—The bottom course of masonry at the base of a foundation.

Irregular Course.—A course in which the thicknesses of the stones vary at intervals.

Random Course.—Same as "Irregular Course," *q.v.*

Regular Course.—A course in which the thickness of stones is uniform throughout.

Ring Course.—A course of masonry parallel to the face of the arch.

Rubble Course.—A course in which rough stones are leveled off at specific heights to an approximately horizontal surface.

Stretcher Course.—A course of masonry consisting entirely of stretchers.

String Course.—A narrow ornamental course carried around a structure.

Coursed Rubble.—See "Rubble."

Coursing Joint.—See "Joint."

Cover Plate.—See "Plate."

Crab.—A short shaft or axle, mounted in a frame, having squared ends to receive hand cranks, used to wind up a rope and thereby raise a load.

Bracket Crab.—A hoisting apparatus fastened to a wall.

Derrick Crab.—A hoisting apparatus at the foot of a derrick. A special crab for a derrick.

[illegible] Crab.—Any crab used for hoisting.

[illegible] Crab or Square End Crab.—A crab having the ends of the shaft squared to [illegible] the cranks or handles.

[illegible].—A term applied to

mass sustained. To

Cradling.—The placing of the cables

the sag than at the supporting towers.

Cramp.—A short bar of metal having

for insertion into two adjoining

together.

Cramp Iron.—Same as a "Cramp," *q.v.*

Cramp Joint.—See "Joint."

Crandall.—A mason's tool consisting of an iron

one end into which are keyed a number of

to dress stone with a crandall.

Crandalled Dressing.—See "Dressing."

Crandalled Masonry.—See "Masonry."

Crane.—A hoisting machine mounted so that it

and thereby place the load at any point within its

Balance Crane.—A crane having two counterpoised

Cantilever Crane.—A crane in which the weight

mass of material such as stone blocks or pig iron.

rotated, the rear end being supported by a circular

Column Crane.—A crane built in the form of a

hang at the top. Also called a "Tower Crane."

Derrick Crane.—A crane in which the post is

the jib being pivoted like the boom of a derrick.

Electric Crane.—A crane operated by electricity.

Gantry Crane.—A crane set upon a gantry, *q.v.*

Hydraulic Crane.—An apparatus for raising and lowering

of a hydraulic press.

Jib Crane.—A crane having a swinging boom.

Locomotive Crane.—A locomotive, or steam engine on

Used in yard work.

Overhead Balanced Crane.—A combination of an overhead

Overhead Crane.—A crane which travels on elevated

Rotary Crane.—A crane having a jib swinging in a

Steam Crane.—A crane operated by steam power.

Swinging Crane.—Any crane which has a boom that swings

Tower Crane.—Same as "Column Crane," *q.v.*

Tram Crane or Traveling Crane.—A crane mounted on

moved from place to place.

Walking Crane.—Same as "Locomotive Crane."

Water Crane.—A crane operated by means of hydraulic

Crane Girder.—See "Girder."

Crank.—A device or mechanism for producing rotation

is a bar or disk set at right angles to the shaft and

from the axis of rotation, to which the force is applied.

A twist or a turn.

Bell Crank.—A bent or rectangular crank lever by which

is changed ninety degrees, and by which the velocity

altered at pleasure through making the arms of different

Disk Crank.—A disk carrying a crank-pin and substituted

Crank Auger.—See "Auger."

Crank Pin.—See "Pin."

Crank Shaft.—See "Shaft."

Creeper Traveler.—See "Traveler."

[illegible]—An oily product obtained from distilled coal-tar with the addition of caustic soda and sulphuric acid.

Creosoted Lath.—See "Lath."

Creosoted Timber.—Timber that has been thoroughly saturated with creosote oil or dead oil.

Crescent Truss.—See "Truss."

Crest.—The top of an embankment. Also the highest water in a flood.

Crib.—An inner lining of a shaft or well, consisting of a frame or box of timbers and a backing of planks, to keep the earth from caving in. To build up a support by placing heavy timbers in layers, the sticks of the consecutive layers generally running in directions at right angles to each other. That portion of the base of a pier lying between the top of the deck above the working chamber and the neat work of the shaft.

Basket Crib.—A form for pier foundations in the shape of a basket. This type was used on the Chelsea Bridge at Boston.

Open Crib.—A crib open at the top and bottom.

Cribbing.—Timbers piled cross-wise in order to form a support for a load.

Crimp.—To offset an angle by bending so that it will fit over the flange of another angle, thus doing away with filler plates beneath.

Crimping-machine.—A machine which crimps angles. Used in bridge shops.

Cripple.—To disable or to weaken. Also to give or to give way.

Crippling Load.—See "Load."

Crippling Stress.—See "Stress."

Critical-speed.—That speed of a train on a bridge which produces the maximum impact.

Cross Beam.—See "Beam."

Cross Bond.—See "Bond."

Cross Bracing.—See "Bracing."

Cross-cut Saw.—See "Saw."

Cross Fibered Wood.—See "Wood."

Cross Frame.—See "Frame."

Cross Girder.—See "Girder."

Cross-grained.—Of irregular or gnarled condition. Applies to timber.

Cross-grained Wood.—See "Wood."

Cross-hairs.—Two very fine hairs or strands of spider's web stretched at right angles to each other across the focal plane in a transit or level.

Cross Hatch.—See "Hatch."

Cross-head.—A machine element having the shape of a "T" or a cross, and running on guides in order to control and steady the motion of another member. Often used on piston rods.

Cross-head Pin.—See "Pin."

Crossing.—An intersection. The place where two roads or railroads cross. The place where a river or stream may be crossed. The term is often used for the bridge crossing the stream or river.

Grade Crossing.—A crossing where both roads or tracks are at the same elevation.

Oblique Crossing.—A crossing in which the intersecting centre lines make an oblique angle with each other.

Overhead Crossing.—A crossing where one road or track is above the other.

Skew Crossing.—Same as "Oblique Crossing," *q.v.*

Square Crossing.—A crossing in which the intersecting centre lines are perpendicular to each other.

Under Crossing.—A crossing where one of the roads or tracks is below the other.

[illegible]—A connection between two parallel tracks.

[illegible]—See "Riveting."

[illegible]

[illegible] "Beam." [illegible]

[illegible] top or crown of the arch [illegible] being made higher than [illegible] top of an arch ring.

Crowned Pulley.—See "Pulley."

Crown Thrust of Arch.—See "Arch."

Crown Tile.—See "Tile."

Crown Valve.—See "Valve."

Crown Wheel.—See "Wheel."

Crucible Cast Steel.—See "Steel."

Crucible Steel.—See "Steel."

Crusher.—A machine that crushes or applies a [illegible] pressive resistance of any substance, for

Crushing.—The breaking down of a material due to the

Modulus of Crushing.—A number denoting the tance of a material.

Crushing Strain.—See "Strain."

Crushing Strength.—See "Strength."

Crystalline.—Consisting of crystals. Relating or definite structure referable to one of the crystalline

Crystalline Fracture.—See "Fracture."

Cubature.—The cubic measure or contents of anything.

Cubic Curve.—See "Curve."

Cull.—To sort out or select material that does specifications. Any piece that has been culled.

Culvert.—A small covered passage for water under a

Arch Culvert.—A culvert having an arch roof.

Box Culvert.—A square or rectangular shaped culvert.

Dive Culvert.—An inverted siphon.

Cumulative Stress.—See "Stress."

Cumulative Vibration.—See "Vibration."

Cup and Ball Joint.—See "Joint."

Cup Dolly.—See "Dolly."

Cup Fracture.—See "Fracture."

Cup Washer.—See "Washer."

Curb.—A broad, flat, circular ring of wood, iron, or of a circular wall, as in a shaft or well, to prevent outer casing of a turbine wheel. The edge of a roadway. The wheel-guard in a bridge. To strength curb.

Curb Chain.—See "Chain."

Curb Girder.—See "Girder."

Curb Stone.—See "Stone."

Curled Wood.—See "Wood."

Current.—The flow of a liquid or gas, or the movement

Air Current.—The moving of air through space or thr

[illegible]

Alternating Current.—An electric current of which the direction of flow reverses a given number of times per second.

Direct Current.—An electric current which flows in the same direction constantly.

Water Current.—A flow of water.

Current Meter.—See "Meter."

Curtain Wall.—See "Wall."

Curvature.—The amount of curving or bending of a line, figure, or body. It is measured by the ratio of the deflection angle between end tangents (measured in radians) to the length of the intervening arc.

Concave Curvature.—The direction of curvature as seen from a point on the chord joining the extremities of the arc. Opposed to Convex Curvature.

Convex Curvature.—The direction of curvature as seen from a point on a tangent to the curve. Opposed to Concave Curvature.

Degree of Curvature.—The angle in degrees subtended by a chord one hundred feet long. Used in railroad location.

Radius of Curvature.—The radius of the circle of curvature.

Curve.—A line continuously bent so that no portion of it is straight. A continuous bending; a flexure without angles. A drafting instrument for drawing curved lines.

Adiabatic Curve.—A curve exhibiting the relation between the pressure and volume of a fluid upon the assumption that there is no transmission of heat during expansion or contraction.

Algebraic Curve.—A curve in which the equations in linear coordinates contain only the algebraic functions of the coordinates.

Catenary Curve.—Same as a "Catenary," *q.v.*

Characteristic Curve.—A curve which shows the relation existing between certain features or properties of a machine or substance.

Compound Curve.—A continuous curve composed of two or more arcs having different radii.

Cubic Curve.—A curve of the third degree.

Cuspidal Curve.—A curve ending in or shaped like a cusp, *q.v.*

Cycloidal Curve.—Same as "Cycloid," *q.v.*

Easement Curve.—A curve of gradually changing radius for passing from a tangent to a circular curve. Used in railroading to ease the train shock that comes from the changing of the direction of motion.

Efficiency Curve.—A curve showing the relation of output to input, or the efficiency of a machine, apparatus, method, etc.

Elastic Curve.—The curve formed by the neutral axis of a beam, as it deflects under the action of its own weight, and of the loads upon it.

Elliptical Curve.—Same as "Ellipse," *q.v.*

Epicycloidal Curve.—Same as "Epicycloid," *q.v.*

Evolute Curve.—Same as "Evolute," *q.v.*

Harmonic Curve.—Same as "Sine Curve," *q.v.*

Hyperbolic Curve.—Same as "Hyperbola," *q.v.*

Inverted Catenary Curve.—A curve formed by revolving the ordinary catenary one hundred and eighty degrees around its major axis.

Involute Curve.—Same as "Involute."

Irregular Curve.—A draftsman's tool for drawing curved lines of varying radii.

Lemniscatic Curve.—Same as "Lemniscate," *q.v.*

Logarithmic Curve.—A curve in which the ordinate are logarithms of the corresponding abscissæ.

[illegible] Spiral Curve.—A spiral curve in which the radius vector varies as the [illegible] of the angles.

Mechanical Curve.—Same as

Natural Curve.—The curve of the

Ogee Curve.—A reverse curve formed by
curvature, used in architecture.

Oval Curve.—Same as "Oval," *q.v.*

Parabolic Curve.—Same as a "Parabola," *q.v.*

Periodic Curve.—A curve which represents a

Plane Curve.—A curve lying in one plane.

Railroad Curve.—Curve used on railways or
or template for drawing such curves.

Regular Curve.—Same as a "Simple Curve," *q.v.*

Reverse Curve.—A continuous curve formed of two

Simple Curve.—In railroad work a circular arc
next; a curve of constant radius.

Sine Curve.—A curve in which the abscissa is
ordinate is proportional to the sine of the angle.

Spiral Curve.—Same as "Spiral," *q.v.*

Transcendental Curve.—A curve expressed by an
functions of one or more of the ordinates.

Transformed Catenary Curve.—Same as "Transformed

Transition Curve.—Same as "Easement Curve," *q.v.*

Vertical Curve.—A curve in a vertical plane, usually
grade tangents of a roadway or railroad.

Curved Girder.—See "Girder."

Curved Line.—See "Line."

Curved Top Chord.—See "Chord."

Cushing Pile.—See "Pile."

Cushion.—A confined body of air or steam which serves
to absorb impact.

Air Cushion.—A buffer using air to absorb impact of a
to bring it to rest.

Cushion-coat.—A layer of material used in pavements, from
placed between the wearing surface and the foundation.

Cusp.—A point in a curve where two branches have a
section of two curves.

Cuspidal Curve.—See "Curve."

Cut Gear.—See "Gear."

Cut Nail.—See "Nail."

Cut-off.—A device for cutting off the passage of steam
the cylinder of an engine. A channel cut through a
straighten a river. That point where piles or timbers
in place.

Cut-off End.—That part of a pile that has been sawed off
in place.

Cut Spike.—See "Spike."

Cut Stone.—See "Stone."

Cut Stone Masonry.—See "Masonry."

Cutter.—A steel tool for cutting metals. Also the
machine.

Bar Cutter.—A shearing machine which cuts metallic bars

Cold Cutter.—Same as "Cold-cut," *q.v.*

Glass Cutter.—A hand tool having a diamond edge
for cutting glass.

Cutter.

Hot Cutter.—A tool for cutting metal which has been softened by heating.

Pinhole Cutter.—An apparatus for cutting pinholes in the chords or web members of a truss.

Pipe Cutter.—A plumber's tool consisting of two beveled edged steel cutting wheels mounted in an adjustable jaw that partly encircles the pipe. A rotation of the tool by a suitable handle and the closing up of the jaws severs the pipe.

Pneumatic Cutter.—A cutter operated by compressed air.

Rivet Cutter.—A hand tool, similar to a cold-cut but with edge sharpened on a more obtuse angle, used for cutting off the heads of driven rivets.

Stone Cutter.—A workman skilled in the art of cutting and dressing stone.

Thread Cutter.—A tool, consisting of a stock and set of dies, used for cutting threads on rods and pipes.

Cutting Edge.—The edge of the tool which does the cutting. The edge of timber or steel angles placed on the bottom of the working chamber of a caisson.

Cutting Tool.—See "Tool."

Cutwater.—A starling; the projecting ends of a bridge pier, etc. Usually so shaped as to allow water, ice, drift, etc. to strike without injury to the structure.

Cycle.—A complete revolution. Any recurring period in which a series of events or phenomena takes place. A series that repeats itself. A series of operations by which any product is finally restored to a primary condition.

Cycloid.—A curve generated by a point on the circumference of a circle when the circle is rolled along a straight line and kept always in the same plane.

Cyclopean Concrete.—See "Concrete."

Cylinder.—A solid of revolution generated by a rectangle rotating about one of its sides. A machine element having a circular bore.

Air Cylinder.—A nearly air-tight hollow cylinder having a piston moving in it.

Steam Cylinder.—The chamber of a steam engine in which the force of steam is exerted on a piston.

Water Cylinder.—The cylinder in a pump by means of which and the moving piston therein water is forced into an exterior main.

Cylinder Pier.—See "Pier."

D

Damper.—A door or valve for admitting air to a furnace

Dangerous Section.—See "Section."

Dap.—To notch a timber on its bearing.

Dapped Joint.—See "Joint."

Dash-pot.—A cylinder containing a loosely fitted piston and partly filled with fluid, used to check sudden movements in the parts of a machine.

Datum.—A fact either indubitably known or treated as such for the purpose of a particular discussion. A known reference. A point, line, or plane used as a basis for referring measurements.

Datum Line.—See "Line."

Datum Plane.—See "Plane."

Day Foreman.—See "Foreman."

Day Superintendent.—See "Superintendent."

Deadening Dressing.—See "Dressing."

Dead Load.—See "Load."

Dead Load Stress.—See "Stress."

Dead-man.—A timber, log, or beam buried in the ground for anchorage.

Dead Melt.—See "Melt."

Dead-points.—The two points in the revolution of a crank where the crank arm is parallel with the rod which connects it with the moving power.

[illegible]

[illegible] Deck.—The bottom deck of a

[illegible] Deck.—The top deck of a

Deck Beam.—See "Beam."

Deck Bridge.—See "Bridge."

Deck Cantilever.—See "Cantilever."

Deck Girder.—See "Girder."

Decking.—Flooring. Same as "Deck," q.v.

Deck Plate Girder.—See "Girder."

Deck Span.—See "Span."

Deck Truss.—See "Truss."

Declivity.—A downward slope or descent of the

Deflection.—A lateral motion, a motion at right
Also the amount of such motion expressed in some

Dynamic Deflection.—The additional deflection
motion.

Static Deflection.—Deflection due to a quiescent

Deflection Indicator or Deflectometer.—An apparatus
of bridge spans.

Deformation.—Change of form. A change of shape in
members without any breach of the continuity of the

Elastic Deformation.—A change of shape without
of the material. A deformation with resulting

Residual Deformation.—Deformation left in a member
have been removed. Same as Permanent Set.

Truss Deformation.—An alteration in the lengths
composing a truss.

Deformed Bar.—See "Bar."

Density.—The mass or amount of matter per unit of volume

Departure.—A term used in surveying to denote the
of two assumed rectangular coordinates—often from
south.

Depreciation.—The loss of value in a plant or structure
measured by the difference between its first cost and
of the allotted time.

Depth.—The downward distance from the surface or top.
the idea of verticality; but such is not always the
of any beam that is inclined to the horizontal is measured
to its length, and, therefore, on a line inclined to the

Arch Depth.—The depth of the arch ring at any point

Economic Depth.—That depth of truss or girder, which
sidered, will give results that are satisfactory from all
the least expenditure of money for properly combined
nance, and repairs.

Effective Depth.—The perpendicular distance between
or girder.

Truss Depth.—The vertical distance between the centre
chords.

Derailing Apparatus.—A device or mechanism used for

Derailing Switch.—See "Switch."

Derrick.—An apparatus for lifting and moving heavy weights. It is similar to the crane; but differs from it in having the boom, which corresponds to the jib of the crane, pivoted at the lower end so that it may take different inclinations.

Bull-Wheel Derrick.—A derrick with a bull wheel attached to the bottom of the mast in order to swing the derrick by ropes running to the hoisting engine.

Floating Derrick.—A movable derrick erected on a special boat, barge, or vessel.

Gin Pole Derrick.—See "Gin Pole."

Gin Type Derrick.—A framework with four stiff legs, used in borings, or for lifting pipes in trenches.

Guy Derrick.—A derrick in which the mast is guyed with cables to an anchorage.

Stiff Leg Derrick.—A derrick where stiff legs, usually of timber, take the place of guy lines for staying the mast. These stiff legs are attached to horizontal timbers which in turn are fastened to the bottom of the mast.

Design.—To proportion all the parts of a structure. A plan, or plans, showing the various parts of a structure, their sizes, and relations.

Detail.—One of the smaller parts into which any construction or design may be divided. To go into particulars. To draw the particular parts.

Detail Drawing.—See "Drawing."

Detailing.—The actual work of planning and drawing the different parts and the connections of any structure. The smaller parts of any construction, speaking of them as a class.

Detail Paper.—See "Paper."

Deviation.—The variation or deflection from a straight line or course.

Diagonal.—A member running obliquely across the panel of a truss. Any oblique line.

Lateral Diagonal.—A diagonal member in a lateral system.

Main Diagonal.—A web diagonal member joining the top and bottom chords of a truss, and taking its greatest stress when not less than one half of the span is covered by the live load.

Sub Diagonal.—An intermediate web diagonal joining a chord with a main diagonal.

Diagonal Bracing.—See "Bracing."

Diagonal Tie.—See "Tie."

Diagonal Wrench.—See "Wrench."

Diagram.—A sketch, outline, or skeleton drawing. A record made by curves plotted on cross-section paper.

Clearance Diagram.—A diagram used in bridge designing showing the horizontal and vertical clearances in a structure.

Displacement Diagram.—A diagram in which the relative position of points represents in magnitude and direction the relative displacement of particles.

Double Tracing Diagram.—A diagram on cross-section paper containing two related groups of curves, and involving four variable quantities. See Figs. 55*uu* and 55*vv*.

Erection Diagram.—A skeleton drawing of a truss or span showing all pieces in their relative positions, properly lettered and numbered in order to facilitate the process of erection.

Force Diagram.—A diagram in which the amounts and directions of forces are represented by lines for the purpose of finding their resultant.

Frame Diagram.—A diagram of a frame in which the positions of the axes of the joints are shown by points, while the rigid connections are shown by lines between them.

Graphic Diagram.—A diagram in which lines are drawn to represent the elements of a problem.

Indicator Diagram.—The diagram showing the relation between pressure and piston travel in an engine cylinder, as traced by indicator.

Diagram.

Load Diagram.—A diagram showing the amounts and arrangement of loads on a structure. The diagram taken off an engine by an indicator.

Locomotive Diagram.—A diagram showing the wheel loads and spacings in a locomotive.

Moment Diagram.—A curve showing the values of the bending moments in a beam or truss at various sections thereof.

Packing Diagram.—A drawing showing the arrangement or packing of the parts of a composite member or the disposition of several members meeting at a panel point. Refers generally to arranging truss members on pins in pin-connected structures.

Shear Diagram.—A diagram showing the variation of the shear along a beam or truss.

Skeleton Diagram.—A diagram which shows the general peripheral outline and the main members in a truss.

Stress Diagram.—A skeleton drawing of a truss, upon which are written the stresses in the different members. Also called "Diagram of Stresses."

Williot Diagram.—See "Williot Diagram."

Diagram of Stresses.—Same as "Stress Diagram," *q.v.*

Diagram of Weights.—A system of right lines or curves giving the weights of metal or portions of same per lineal foot of structure for bridges, trestles, etc.

Diametral Pitch.—See "Pitch."

Diametral Plane.—See "Plane."

Diamond Drill.—See "Drill."

Diaphragm.—A thin plate or partition across a bridge member to stiffen the same.

Diaphragm Plate.—See "Plate."

Die.—A steel former or device for shaping, impressing, or cutting out something.

Pipe Die.—A tool for cutting threads on a pipe.

Dies.—Two flat plates of hardened steel having a semi-circular groove cut in the edges making contact with each other. This groove has an internal thread, so that when the two pieces are brought together in a stock a female screw is formed. It is used for cutting threads on rods, bolts, etc.

Die Stock.—See "Stock."

Differential.—An infinitesimal difference between two values of a variable quantity. Also often used for the expression "differential gear."

Differential Block.—See "Block."

Differential Capstan.—See "Capstan."

Differential Coefficient.—See "Coefficient."

Differential Coupling.—See "Coupling."

Differential Gear.—See "Gear."

Differential Jack.—See "Jack."

Differential Pulley.—See "Pulley."

Differential Screw Jack.—See "Jack."

Differential Tackle.—Same as "Differential Block," *q.v.*

Differential Windlass.—See "Windlass."

Dike or Dyke.—A mound of earth built to prevent the overflow of rivers or of the sea; also to keep the channels of rivers, streams, etc., in one position. A timber construction to protect a river bank against erosion or to form land by deposition of sediment.

Puddle Dyke.—A dyke with a puddle wall running longitudinally through it.

Dimension.—Bulk, size, extent, or capacity. The length, width, height, etc., in units of measure.

Dimension Stone.—See "Stone."

Dinkey Engine.—Same as "Dinkey Locomotive." See "Locomotive."

Dinkey Locomotive.—See "Locomotive."

Dip.—The inclination to the horizontal of any stratum of earth or rock.

Dipper Dredge.—See "Dredge."

Direct Stress.—See "Stress."

Direct Tension.—See "Tension."

Direct Wind Load Stress.—See "Stress."

Disc or **Disk.**—A flat circular piece of material.

Screw Disc.—A plate or casting circular in plan, shaped like the thread of a screw, or having a helicoidal surface.

Discharge.—A flowing out. Used in connection with the amount of liquid passing through an orifice in a unit of time, or the amount of water in a stream passing a given cross-section in a unit of time.

Discharge Valve.—See "Valve."

Discount.—An amount deducted from a sum owing, or to be paid. To deduct such a sum of money.

Bank Discount.—The advanced payment of interest demanded by the bank at the time of making a loan. It is computed as simple interest on the face value of the note for the time given.

True Discount.—The present worth of the interest computed on the face value of the note.

Disk.—Same as "Disc," *q.v.*

Disk Coupling.—See "Coupling."

Disk Crank.—See "Crank."

Disk Pile.—See "Pile."

Displacement Diagram.—See "Diagram."

Ditch.—A trench made by digging. A narrow open passage for water on the surface of the ground.

Dive Culvert.—Same as "Syphon," *q.v.*

Diving-bell.—A mechanical contrivance consisting of an inverted, or bell-shaped, chamber filled with compressed air in which persons are lowered beneath the water for the examination of the foundation of bridges, etc.

Diving Dress or **Diving Suit.**—A submarine armor used for the same purpose as that of a diving bell, *q.v.*

Division Wall.—See "Wall."

Dock.—An enclosed, or partially enclosed, water-space in which vessels, barges, etc., are loaded and unloaded.

Dry Dock.—A dock from which water is withdrawn after the vessel is floated in for repairs.

Wet Dock.—A dock where vessels are placed to load and unload.

Dog.—A name for various mechanical devices, tools, etc., that usually grip something. The grappling iron which lifts the monkey, or hammer, of a pile driver. Any part of a machine acting as a claw or clutch. A click or pallet which restrains the back action of a ratchet wheel.

Bench Dog.—A hook-shaped iron fastened to a bench for holding in place materials, such as wood.

Cant Dog.—Same as "Cant Hook," *q.v.*

Chain Dog.—A lumber chain having on each end a hook to be driven into logs that go to make up a raft.

Eye-bar Dog.—A special pair of tongs for lifting and moving eye-bars.

Girder Dogs.—A special pair of dogs used for lifting and moving girders.

I-Beam Dog.—A special pair of dogs for lifting and moving I-beams.

Raft Dog.—An iron bar with ends bent over and pointed for securing logs together in a raft.

Ring Dogs.—A pair of dogs connected by a ring.

[illegible]

[illegible]—A special pair of [illegible]

[illegible]—See "Head."

[illegible]—See "Hook."

[illegible]—A short bar of iron [illegible] angles and pointed so as to hold [illegible] Often the term "Dog Iron" is used [illegible]

Dolly.—An extension piece placed on the [illegible] is below the leads of the pile driver and [illegible] A snap head; a tool with an indented head [illegible] absorbing impact while the other head is [illegible]

Air Dolly.—A dolly operated by compressed air. [illegible]

Bar Dolly.—A goose-neck or horse-dolly which [illegible] at each end.

Bent Club Dolly.—A club dolly having a bend in the [illegible]

Bent Dolly.—A dolly with a bent offset at the [illegible] cup-shaped indentation for the rivet heads.

Club Dolly.—A dolly with a steel hammer head [illegible] smaller end of the hammer head has a cup-like [illegible] head. Usually a maul is held against the big end of [illegible] are being driven.

Combination Dolly.—A double headed tool [illegible] rivets. Usually balanced on a chain.

Corrugated Dolly.—A straight dolly with one [illegible] knob.

Cup Dolly.—Any dolly that has a cupped end for [illegible]

Flat Dolly.—A hammer headed dolly, flat on both [illegible]

Goose-neck Dolly.—A dolly that has a quickly [illegible] ends arranged for receiving rivet heads.

Heel Dolly.—A tee-headed dolly, having the far end [illegible] eighths (⅞) inch bolt located one and seven-eighths [illegible] centre of the tee head. Also a dolly with a long [illegible] bend at one end, the cup being in the short end.

Horse Dolly.—Same as a "Goose-neck Dolly," *q.v.*

Ring Dolly.—A dolly having a handle attached to two [illegible] have a series of holes near the circumference on one [illegible] other. A tap bolt goes through any of the holes and [illegible] placing the bucking bar at any angle required.

Screw Dolly.—A straight dolly with a shaft that screws [illegible] beams for bucking up.

Spring Dolly.—A dolly having a heavy hammer head [illegible] Each end of the hammer has a cup to receive the [illegible] driving.

Straight Dolly.—A cup-shaped dolly with a straight [illegible]

Dolly Bar.—See "Bar."

Dolomitic Limestone.—See "Limestone."

Dolphin.—A cluster of piles driven some distance ahead [illegible] span piers of an opening bridge to protect the [illegible] from passing vessels.

Donkey Engine.—See "Engine."

Donkey Pump.—See "Pump."

Dorchester Sandstone.—See "Stone."

Doty Tie.—See "Tie."

Double Bitted Axe.—See "Axe."

Double Blocks.—See "Blocks."

Double Bowstring Truss.—See "Truss."

Double Cancellation.—See "Cancellation."

Double Cap.—See "Cap."

Double Concentration.—See "Concentration."

Double Deck.—See "Deck."

Double Drill.—See "Drill."

Double Ender Locomotive.—See "Locomotive."

Double End File.—See "File."

Double-faced Hammer.—See "Hammer."

Double Flemish Loop Knot.—See "Knot."

Double Intersection.—Same as "Double Cancellation," *q.v.*

Double Intersection Truss.—See "Truss."

Double Joint.—See "Joint."

Double Knot.—See "Knot."

Double Lacing.—See "Lacing."

Double Latticing.—Same as "Latticing," *q.v.*

Double Locomotive Excess-load.—See "Locomotive Excess-load."

Double Piston Locomotive.—See "Locomotive."

Double Refined Iron.—See "Iron."

Double Rim Bearing Draw.—See "Draw."

Double Rim Bearing Turntable.—See "Turntable."

Double Riveted Lacing.—See "Lacing."

Double Riveting.—See "Riveting."

Double Rotating Cantilever Draw.—See "Draw."

Double Shear.—See "Shear."

Double Shear Steel.—See "Steel."

Double Speed Pulley.—See "Pulley."

Double Triangular Truss.—See "Truss."

Double Truck Tank Locomotive.—See "Locomotive."

Double Wrench.—See "Wrench."

Douglas Fir.—A species of the pine family found on the Pacific Coast. Grows very large and furnishes hard durable timber.

Dovetail.—A manner of making joints by having a series of projections in one piece fitting into corresponding recesses in another piece. A joint in carpenter work. It is a poor joint in timber where much stress has to be provided for. The shape of the tongue of the joint is like that of the spread tail of a dove.

Dovetail Joint.—See "Joint."

Dowel.—A straight pin of wood or metal driven part way into each of the two faces which it unites. Also called a dowel-pin.

Dowel Joint.—See "Joint."

Dowel Masonry.—See "Masonry."

Draft.—The depth to which a floating vessel or box sinks in the water. Also a cut or a groove.

Chisel Draft.—A tool used for drafting stone. The cut in stonework made by such a tool—generally at the edges of the stones.

Margin Draft.—A chisel draft around the edges of a stone.

Drafted Dressing.—See "Dressing."

Drafted Stone.—See "Stone."

Drainage.—The run-off in a drainage area. A system of piping to carry off water.

Drainage Area.—See "Area."

Draught.—A drawing. A narrow level strip which a stone-cutter first cuts around the edges of a rough stone, to guide him in dressing off the face thus enclosed by the draught. To make drawings. Spelled also "draft."

Draw.—The movable portion of a draw-bridge. To make drawings. To haul.

Centre Bearing Draw.—A swing span supported on a central pivot.

Double Rim Bearing Draw.—A draw span supported on two rims or a double drum.

Double Rotating Cantilever Draw.—A movable structure composed of two adjacent swing spans, the inner ends of which are mechanically connected, and the outer ends of which engage with anchorages.

Revolving Draw.—A draw which turns in a horizontal plane.

Rim Bearing Draw.—A swing span supported on a rim or drum.

Rotating Draw.—Same as "Revolving Draw," *q.v.*

Wedge Bearing Draw.—A swing span in which the live load, or a portion thereof, is carried by wedges under the chords of the trusses.

Draw Bridge.—See "Bridge."

Drawing.—The act of pulling or hauling. The making of a plan on paper, etc. Also the plan itself.

Detail Drawing.—A drawing on a large scale showing all small parts, dimensions, details, etc.

Erection Drawing.—Same as "Erection Diagram." See "Diagram."

General Drawing.—A drawing showing the elevation, plan, and cross-section of the structure—also the borings for substructure and the main dimensions.

Perspective Drawing.—A drawing showing in perspective any structure. See "Perspective."

Picture Drawing.—A general drawing attempting to show as a picture the actual way the structure would look.

Shop Drawing.—A drawing of a structure or machine showing all parts and dimensions so that the shop can actually build what is indicated on the drawing without other information.

Skeleton Drawing.—Same as "Skeleton Diagram." See "Diagram."

Working Drawing.—Any drawing showing all the parts and dimensions with other information pertinent to construction, so that whatever is shown can be built without other drawings or instructions.

Drawing Down.—Reducing gradually the sectional area.

Draw Plate.—See "Plate."

Draw Rest.—A pile and timber structure, ballasted with rock, built approximately at right angles to the bridge tangent and extending up and down stream so as to underlie the draw span when it is open, thereby affording protection from passing vessels and providing a support for the ends of the span when open. Built sometimes of masonry.

Draw Span.—See "Span."

Dredge.—An apparatus or machine for lifting mud, sand, silt, and small boulders from the bottom of a stream or the bed of an arm of the sea. To excavate with a dredge.

Bucket Dredge.—A dredge which hoists out the material by the use of buckets usually attached to an endless chain.

Clam-shell Dredge.—A dredge using a clam-shell bucket attached to a hoisting apparatus like a derrick.

Dipper Dredge.—A dredge using a dipper or cubical bucket mounted on the end of a boom.

Featherstone Dredge.—One of the many types of dipper dredges.

Ladder Dredge.—A dredge having buckets mounted on an endless, ladder-like chain.

Orange-peel Dredge.—A dredge using an orange-peel bucket attached to a hoisting apparatus like a derrick.

Dredge.—A dredge provided with one or more scoops.

Dredge.—A dredge operated by steam.

ed Ashlar.—See “Ashlar.”

ing.—The sizing, shaping, and facing of stones for masonry work.

d Dressing.—A finish in stonework as left by the mason's axe in dressing the face to a plane surface.

sted Dressing.—A finish in stonework wrought with a chisel or narrow tool.

ached Dressing.—A finish in stonework wrought with a “punch” after the surface has been droved.

ken Axed Dressing.—A stonework dressing made with an axe to resemble “Crandalled Dressing,” *q.v.*

h Hammered Dressing.—A finish in stonework wrought with a bush hammer.

iseled Dressing.—Same as “Boasted Dressing,” *q.v.*

lumnar Stroked Dressing.—A droved dressing in masonry in which the flutes are like those in a column.

andalled Dressing.—A finish in stonework in which the face of the stone is dressed to a plane with a crandall.

eadening Dressing.—The crushing or crumbling of soft stone under the tools while being worked, leaving irregularities in the finished surface.

afted Dressing.—A finish in stonework having a narrow chisel-draft cut around the face or margin.

oved Dressing.—A finish in stonework wrought with a broad chisel or hammer in parallel flutings across the face from end to end.

rous Stroked Dressing.—A stroked dressing in masonry in which the flutings are made wavy and like fibres in appearance.

e Pointed Dressing.—A type of stone dressing in which the surface left by rough pointing is reduced to a degree of smoothness such that no part projects more than a quarter of an inch beyond the pitch face.

mmered Dressing.—A finish in stonework wrought with a mason's hammer.

ring Bone Dressing.—A type of stone dressing made by cutting flutings in a diagonal direction on the face of the stone.

gged Dressing or **Nigged Dressing.**—In stonework a finish picked with a pointed hammer or cavil.

tent Hammered Dressing.—A form of stone facing made with a patent hammer.

n Hammer Dressing.—A form of stone facing made with a pean hammer.

ed Dressing.—A facing of stonework made by a mason's pick in reducing the surface to an approximate plane.

ed Dressing or **Pitched Faced Dressing.**—In stonework, a finish dressed to neat lines or edges with a pitching chisel.

n Dressing.—In stonework, a facing rubbed smooth to remove tool marks.

ted Dressing.—A form of stone facing made by chipping off projections with a mason's point or similar tool.

ed Dressing.—A finish in stonework made by rubbing a tooled surface down to a reflecting surface.

Dressing.—A type of stone dressing in which the surface is wrought into [illegible]

Faced Dressing.—Same as “Rock Faced Dressing,” *q.v.*

Tooled Dressing.—In stonework a finish cut with a broad tool into irregular [illegible]

ed Dressing.—The facing on stonework left rough as it comes from the [illegible] It may be drafted or pitched so as to reduce projecting points on the face [illegible] limits.

ing.—Same as “Rustic Dressing,” *q.v.*

[illegible] or [illegible]

[illegible] Dressing.—A form of stone [illegible]
[illegible] projections of the stone [illegible]

Smooth Dressing.—Same as "Plain Dressing."

Square-Droved Dressing.—A finish [illegible] dicular to the lower edge of the stone [illegible]

Stippled Dressing.—A dressing in stonework [illegible] producing parallel grooves.

Stroked Dressing.—Same as "Droved Dressing."

Tooled Dressing.—A dressing in stonework [illegible] to a plane.

Tooth-axed Dressing.—A form of stonework dressing [illegible]

Toothed Dressing.—A type of stone dressing [illegible]

Vermiculated Dressing or Worm Work Dressing.—[illegible] which veins are made by cutting away portions [illegible]

Drier.—A material containing metallic compounds [illegible] materials for the purpose of accelerating the [illegible]

Drift.—A horizontal or inclined passage in a tunnel [illegible] Débris, such as trees, timbers, brush, etc., [illegible] holes in steel work by drift-pins. To swing [illegible] of a double set of ropes and blocks, one set [illegible] To enlarge a hole with a conical pin.

Drift Bolt.—See "Bolt."

Drift Ice.—Masses of detached floating ice which drift [illegible]

Drift-pin.—A short, tapered rod for enlarging rivet holes [illegible]

Drill.—To bore a hole in a material with a tool revolved [illegible] The tool itself or the apparatus holding and turning it.

Calyx Core Drill.—A drill for making borings in earth [illegible] shank having a hollow steel bit under which chilled [illegible] The rotation and pressure cause the shot to mill [illegible] of it sticking upward inside the drill. At suitable [illegible] and brought to the surface for examination.

Centre Drill.—A drill for making a central hole, as in [illegible]

Churn Drill.—A steel bar about eight feet long having [illegible] for drilling into hard strata.

Clamp Drill.—A drill having a clamp to hold it to the [illegible]

Core Drill.—A rock drill having a hollow cutter so that [illegible] out which extends upward into the interior of the drill [illegible] intervals the core is broken off and brought to the surface [illegible]

Countersink Drill.—A tool combining a drill and a countersink [illegible]

Diamond Drill.—A type of core drill using black diamonds [illegible] which is revolved by a shaft extending to the ground [illegible] with suitable driving machinery.

Double Drill.—A drill with two cutters for making [illegible]

Fluted Drill.—A drill having two longitudinal grooves [illegible]

Forked Drill.—A slotted tool with a forked point used [illegible]

[illegible]

Gang Drill.—A machine tool containing in one head a number of vertical drills, each having its separate belt and pulley operated from a common shaft.

Hand Drill.—Any drill that is operated by hand. Usually one man operating both drill and hammer.

Jumper Drill.—A drill similar to a churn drill only much shorter.

Machine Drill.—A drill mounted in a machine and run by power.

Percussion Drill.—A solid drill-rod having an action like that of a churn drill.

Pin Drill.—A drill for boring pin holes in truss members.

Pneumatic Drill.—Any drill operated by air.

Radial Drill.—A machine rock drill in which the drill tool is fastened to a radial arm.

Ratchet Drill.—Any drill operated by a ratchet mechanism.

Rock Drill.—Any drill used for quarrying rock.

Rose Drill.—A drill with a cylindrical cutting face.

Rotating Drill.—A drill having a rotating motion instead of a churning motion.

Socket Drill.—A drill having a shank that fits into a socket.

Stone Drill.—A bar used to cut holes in stones and rocks.

Straight Shank Drill.—A drill having a straight shank, in contra-distinction to a tapered shank, *q.v.*

Taper Shank Drill.—A drill having a tapered shank.

Teat Drill or Tit Drill.—A square-faced cylindrical drill, with a sharp, pyramidal projection issuing from the centre of the cutting face.

Twist Drill.—A cylindrical drill having two parallel, spiral grooves on opposing sides and the point sharpened to an obtuse angle.

Barrow.—Same as "Drill," *q.v.*

bit.—The cutting tool used in a drilling machine. Also called "Drill," *q.v.*

Chuck.—See "Chuck."

Gauge.—See "Gauge."

Machine.—A machine for boring holes in metals, rock, etc.

ings.—The cuttings, or shavings, arising during the process of drilling. Also the holes that are drilled in the ground.

Plate.—A breast-plate for hand-drilling operations.

Press.—See "Presses."

Scow.—See "Scow."

Stock.—See "Stock."

—A small channel cut under the lower projecting edge of a coping, etc., so that when rain reaches that point, it will drip or fall off.

Pipe.—See "Pipe."

Stone.—See "Stone."

Pulley.—See "Pulley."

—One of the large wheels which drive any machine or apparatus.

Locomotive Driver.—One of the large driving wheels of a locomotive. Also the man who operates or drives a locomotive.

Axle.—See "Axle."

Belt.—See "Belt."

Box.—See "Box."

—In steel work, a fitting for a bolt so tight that the diameter of the hole is practically the same as that of the bolt, which has to be driven in place with a hammer.

Gear.—See "Gear."

—See "Nut."

Pulley.—See "Pulley."

—See "Shaft."

—See "Wheel."

Drop.—A contrivance arranged so as to hang, drop, or fall from a higher position to a lower one.

Drop of Beam.—A term used in testing materials to indicate that a test piece has passed the yield point as shown by the sudden dropping of the weighing beam of the testing machine.

Drop Forging.—See "Forging."

Drop Hammer.—See "Hammer."

Drop Hammer Pile Driver.—See "Pile Driver."

Droved Dressing.—See "Dressing."

Drum.—A revolving cylinder around which ropes or belts either travel or are wound. The main portion of a turntable for either locomotives or swing spans.

Friction Drum.—Any drum operated by the action of friction.

Dry Masonry.—See "Masonry."

Dry Puddling.—See "Puddle."

Dry Rot.—See "Rot."

Dry Seam.—See "Seam."

Duchemin's Formula.—A wind pressure formula for surfaces inclined to the direction of the wind,

$$P_n = P\frac{2\sin A}{1+\sin^2 A}$$

where

P_n = the normal component of wind pressure,

P = the pressure per square foot on a vertical surface,

A = the angle of inclination of the surface with the horizontal.

Dump.—The place where material such as earth, clay, rock, etc., is deposited. To deposit such material.

Dump Car.—See "Car."

Dump Scow.—See "Scow."

Dumpy Level.—See "Level."

Duplex Hammer.—See "Hammer."

Duplex Slide Rule.—See "Slide Rule."

Durometer.—An apparatus for testing the hardness of steel rails.

Dust Guard.—See "Guard."

Dutch Brick.—See "Brick."

Dutchman.—A wooden block or wedge used to hide an opening in a badly made joint.

Duty.—The number of foot-pounds of work delivered for each hundred pounds of coal burned under a boiler. Also the number of foot-pounds of work delivered for each one thousand pounds of dry steam.

D-Valve.—See "Valve."

Dyke.—Same as "Dike," *q.v.*

Dynamic Deflection.—See "Deflection."

Dynamic Equilibrium.—See "Equilibrium."

Dynamic Horsepower.—Same as "Indicated Horsepower." See "Horsepower."

Dynamics.—That branch of the science of mechanics which treats of the motion of bodies and of the forces acting thereon.

Dynamite.—An explosive of great power, consisting of a mixture of nitroglycerin with some absorbent material such as sawdust. To blow up, destroy, or break up with dynamite.

Dynamo.—A machine for converting mechanical power into electrical power or *vice versa*. In the latter case the machine is called a motor. The essential elements are a field of magnetic flux, produced usually by electro-magnets called field magnets, and a moving set of conductors passing through the magnetic flux so as to cut the lines of force. The moving set of conductors is called the armature.

Dynamometer.—An apparatus for measuring the amount of pull exerted by any machine or engine.

E

Ead's Pump.—See "Pump."

Earth Pressure.—See "Pressure."

Easement Curve.—See "Curve."

Eccentric.—Out of centre. A disk mounted out of centre on a driving shaft and surrounded by a collar or a strap connected with a rod. Its purpose is to convert rotary motion into reciprocating rectilinear motion.

Eccentric Axis.—See "Axis."

Eccentric Gear.—See "Gear."

Eccentricity.—The state or condition of being eccentric. Deviation from a centre.

Economic Depth.—See "Depth."

Economics.—The science of obtaining a desired result with the ultimate minimum expenditure of effort, money, or material.

Eddy.—A whirl or backward current of water. A vortex. That portion of the water in a stream that actually swirls.

Edge.—The sharp margin, or the thin, bordering or terminal line of a cutting instrument. The extreme margin of anything. The brink.

Edger.—A cement finisher's tool for rounding the corners of cement or concrete constructions.

Effective Area.—See "Area."

Effective Depth.—See "Depth."

Effective Horsepower.—See "Horsepower."

Effective Length.—See "Length."

Effective Span.—See "Span."

Efficiency.—The ratio of energy utilized divided by the energy expended.

Efficiency Curve.—See "Curve."

Efflorescence.—A powder-like incrustation formed on bodies such as concrete, metals, etc.

Egg-shell Paper.—See "Paper."

Ejector.—A device for utilizing the momentum of a jet of steam or air under pressure to lift a liquid or a finely divided solid.

Ejector Condenser.—See "Condenser."

Elastic Arch.—See "Arch."

Elastic Curve.—See "Curve."

Elastic Deformation.—See "Deformation."

Elasticity.—That property which many bodies have of recovering their original form after the removal of the deforming cause.

Coefficient of Elasticity or **Modulus of Elasticity.**—The ratio of the direct stress per unit of area to the corresponding relative deformation, sometimes called Lineal Modulus. The numerical value is equal to the stress per unit of area in tension that would be required to double the length of a piece, were the material of which it is composed perfectly elastic. Also called "Young's Modulus."

Shearing Modulus of Elasticity.—The ratio of the unit shearing stress to the accompanying angular deformation. It generally equals two-fifths of the lineal modulus. See "Modulus of Elasticity."

Volumetric Modulus of Elasticity.—The ratio of the unit stress, applied on the three principal axes, to the relative change in volume. It generally equals two-thirds of the lineal modulus.

Elastic-limit.—The unit stress at which the deformation begins to increase in a faster ratio than the applied loads.

[illegible]

[illegible]—See "[illegible]"

[illegible]—See "Locomotive." [illegible]

[illegible]—See "Resistance." [illegible]

[illegible]—See "Connection." In [illegible]

[illegible] Motor.—See "Motor." [illegible]

[illegible]—A magnet which [illegible] flux set up by an electric current flowing [illegible]

Element.—That of which anything is in part [illegible] is itself not decomposable into parts of [illegible]

Truss Element.—A component part of a truss. [illegible]

Elevation.—The altitude or height above [illegible] level, low water, etc. The act of raising [illegible] plane, used in drafting.

Super-elevation.—The height of the outer rail [illegible] tracks. The rails are thus placed in order [illegible] train going at high speed to fly off the [illegible] by the speed and degree of curvature. [illegible]

Elevator.—An apparatus for hoisting loads. A [illegible] hoisting apparatus: *i.e.*, the shaft, cage, and [illegible]

Hydraulic Elevator.—An elevator operated by some [illegible]

Pneumatic Elevator.—A hoisting apparatus operated [illegible]

Ellipse.—A curve such that the sum of the distances from [illegible] foci, to any point on the curve is a constant.

Ellipse of Stress.—See "Stress."

Elliptical Arch.—See "Arch."

Elliptical Curve.—Same as "Ellipse," *q.v.*

Elongation.—The stretching or extension of a part beyond [illegible]

Embankment.—A bank, a dike, or an earthwork raised [illegible]

Emerson's Foundation Pump.—See "Pump."

Empirical.—Pertaining to or derived from experience [illegible]

Empirical Coefficient.—See "Coefficient."

Empirical Formula.—See "Formula."

Encased Knot.—See "Knot."

End Floor-beam.—See "Floor-beam."

Endless Chain.—See "Chain."

End-lifting Apparatus.—An apparatus consisting of a [illegible] lifts and latches the ends of a swing span.

End Pin.—See "Pin."

End Post.—See "Post."

End Reaction.—See "Reaction."

End Shear.—See "Shear."

End Stiffeners.—See "Stiffeners."

Energy.—The capability of doing work.

Conservation of Energy.—The doctrine that the [illegible] universe neither diminishes nor increases, though [illegible] successively.

Hydraulic Energy.—The energy of water in motion.

Kinetic Energy.—Energy that is due to motion.

Potential Energy.—Energy that is due to position.

[illegible] is the sum of the kinetic and the potential energies [illegible]

[illegible]gage.—To bring two pieces into contact. To mesh, as to connect gears. [illegible]

[illegible]ine.—An apparatus or machine for converting some form of energy into [illegible] power for the doing of useful work.

Assistant Engine.—A steam or hydraulic motor used to control the [illegible] of a marine engine, or to turn the shaft when the main engine is at rest.

Dinkey Engine.—Same as "Dinkey Locomotive."

Donkey Engine.—A small stationary steam engine attached to a larger one; a subsidiary engine used for hoisting.

Gas Engine.—An internal combustion engine using gas as a fuel.

Gasoline Engine.—An internal combustion engine using gasoline as a fuel.

Hoisting Engine.—An engine used to operate hoists, derricks, pile drivers, etc.

Internal Combustion Engine.—An engine in which the fuel, such as gas, gasoline, or oil is burned direct in the cylinder, generating a high temperature and high pressure in the gases of combustion, which expand behind a piston and drive it forward.

[illegible]ck Engine.—A small engine employed in sinking a shallow shaft, a donkey engine.

Monkey Engine.—A hoisting engine used to raise a pile-driver hammer.

Stationary Engine.—An engine that rests on a fixed foundation and is not movable.

Steam Engine.—An engine in which a portion of the heat energy of the fuel is conveyed to the cylinder by means of steam, which expands behind the piston and drives it forward.

[illegible]ineering News Formula.—A formula proposed by the late A. M. Wellington, C.E., for determining the safe load on piles.

$$\text{Safe Load} = \frac{2\,W\,H}{s + 1}.$$

where

W denotes the weight of the drop or steam hammer;
H denotes the fall in feet or the stroke in a steam hammer;

and

s denotes the average penetration of the pile per blow in inches under the last few blows.

For steam hammer work this formula is modified by substituting 0.1 in place of unity in the denominator.

[illegible]neer's Hammer.—See "Hammer."

[illegible]neer's Level.—See "Level."

[illegible]neer's Scale.—See "Scale."

[illegible] Bond.—Same as "Old English Bond." See "Bond."

[illegible]rged Scale.—See "Scale."

[illegible]asis.—A slight convex curve in the vertical outline of a pilaster or of the shaft of a column.

[illegible]cycloid.—A curve generated by the motion of a point on the circumference of a circle which rolls on the convex side of a fixed circle.

[illegible]cycloidal Tooth.—See "Tooth."

[illegible]lizer.—An adjuster; a leveler. A device for distributing a load equally over several [illegible].

[illegible]—A state of balance produced by the counteraction of two or more forces. [illegible] state of a body so acted upon by a balanced system of forces that it has no [illegible] to change its condition of motion or rest.

[illegible] Equilibrium.—That condition of a body in uniform motion in which the [illegible] of all the forces acting thereon is zero.

[illegible]

followed by a return to the original po

Static Equilibrium.—That condition of a

the forces acting thereon is zero. There

Stable, Unstable, and Indifferent.

Unstable Equilibrium.—That condition of

is followed by a further displacement.

Equilibrium of Three Parallel Forces in One

See "Lever."

Equilibrium Polygon.—See "Polygon."

Equivalent Uniform Live Load.—See "Load

Erecting-bill.—A bill of material for a bridge,

and placing of members during erection.

Erection.—The assembling of the members of a

necessary permanent connections.

Erection Car.—See "Car."

Erection Diagram.—See "Diagram."

Erection Drawing.—Same as "Erection Diagram."

Erection Gang.—See "Gang."

Erection Stress.—See "Stress."

Escarpment.—A nearly vertical natural face of

Estimate.—To figure quantities, weights, costs, etc. A

weights, costs, etc.

Euler's Formula.—A formula expressing the

ling, viz.,

$$P = \frac{a \pi^2 E I}{l^2}$$

where P = the external load or pressure.

E = the modulus of elasticity.

I = the least moment of inertia.

l = length.

a = constant depending on end conditions.

π = 3.14159.

Even Bearing.—See "Bearing."

Evolute.—A curve which is the locus of the centre of

the envelope of the normals to the latter.

Excavating Shaft.—See "Shaft."

Excavation.—The act of taking out material. An

hollow or cavity formed by removing the interior

Excavator.—A horsepower or steam-power machine for

earth, loose gravel, sand, or any kind of soil.

Pneumatic Excavator.—An excavator operated by

Excentric.—Same as "Eccentric," *q.v.*

Excentric Load.—See "Load."

Excess Load.—See "Load."

Expanding Reamer.—See "Reamer."

Expansion.—Enlargement, lengthening due to heat, or

Coefficient of Expansion.—The amount of expansion

substance, per unit of agent causing the effect.

lineal expansion of a bar of steel for an increase

per unit of length per degree of temperature.

Bearing.—See "Bearing."

Bolt.—See "Bolt."

nsion-end.—The movable end of a structure, trestle, span, truss, etc.

nsion Girder.—See "Girder."

nsion Joint.—See "Joint."

nsion Pocket.—See "Pocket."

nsion Roller.—See "Roller."

sive.—Pertaining to, or of the nature of, explosion. Any substance by the decomposition of which gas is generated with such great rapidity that an internal pressure is suddenly set up, producing the effect of tremendous impact, and the rupture of the restraining medium.

ansion Bar.—See "Bar."

ansion Plate.—See "Plate."

ensometer.—An apparatus for measuring minute degrees of expansion or contraction in metal bars under the influence of temperature or under stress.

ernal Wall.—See "Wall."

rados.—The convex curve of a masonry arch. The upper surface of the voussoirs when in position.

reme Fibre.—See "Fibre."

treme High Water.—See "Water."

treme High Water Mark.—See "Water."

e.—The hole in the end of a member to permit the passage of a pin.

lt Eye.—The eye in an "Eye Bolt," *q.v.*

oop Eye.—An eye on the end of a rod or square bar elongated in the form of a loop.

otted Eye.—An oval eye in the end of an eye-bar in place of the usual round hole.

and Strap.—A hinge which fits over an eye.

-bar.—A bar with an eye at either one end or each end.

Adjustable Eye-bar.—An eye-bar that can be lengthened or shortened after erection by means of a sleeve-nut, turn-buckle, or clevis.

Trussed Eye-bar.—An eye-bar supported by trussing so as to resist compression or bending.

e-bar Dog.—See "Dog."

e-bar Head.—See "Head."

e-bar Hook.—See "Hook."

-bar Upsetter.—A machine for enlarging the end of a plain bar sufficiently to permit the forming of an eye that will develop the full strength of the bar.

e Bolt.—See "Bolt."

-piece.—The lens in the small end of a transit or level.

e Splice.—See "Splice."

F

ation.—The act or process of framing and fitting rolled steel shapes for structures. The putting together of parts of a structural steel construction and riveting them.

ade.—An elevation or exterior face of a building, usually the front or chief face.

—A plane, exterior face of a solid. The front view or exposed part. The working or cutting portion of a grinding-wheel, or the edge of any cutting tool. To prepare or polish a face.

Joint.—See "Joint."

Tooth.—See "Tooth."

—See "Wall."

A layer of earth, turf, or stone laid upon the sloping sides of a railroad em- or other inclined earthwork in order to protect the exposed surface it a steeper slope than generally is natural.

[illegible]

[illegible], bucket, etc.

False Cap.—See "Cap."

Falsework.—The scaffold or temporary
Usually a temporary timber

Flying Falsework.—A type of falsework
bridges. It consists of a horizontal
with a set of heavy girders under
a bearing for the jacks to work against.
two ties, consisting of eye-bars, which
panel point erected. The rear end of the
pier for the first panel erected and then
succeeding panels.

Lower Falsework.—The falsework built below

Upper Falsework.—The falsework above the
no longer used in erection, as its object is
which apparatus has replaced it entirely.

Falsework Bolts.—Any bolts used in tying wooden

Falsework Cap.—See "Cap."

Falsework Pile.—See "Pile."

Fan-tail Joint.—See "Joint."

Fascia.—Any flat member or moulding with but little
portion.

Fascia Girder.—See "Girder."

Fascine.—A bundle of brush wired together and used
protection work to prevent the washing away of the
q.v.

Fastening Angle.—Same as "Connecting Angle." See "

Fast Joint.—See "Joint."

Fast Pulley.—See "Pulley."

Fat Lime.—See "Lime."

Fatigue of Metal.—See "Metal."

Faucet.—A device fixed in a receptacle or pipe to control

Feather.—A longitudinal, projecting guide on a shaft.
of metal placed in a hole in conjunction with a plug

Plug and Feathers.—A combination of two feathers
in a hole in a rock, the plug being driven with a
pressure is produced and the rock broken.

Feather and Wedge.—A single feather combined with a
splitting rock.

Feather-edge.—Any edge that is thin and sharp like a
that is thinner than the other.

Feather-edge Brick.—See "Brick."

Featherstone Dredge.—See "Dredge."

Feed Water Pump.—Same as "Donkey Pump." See "

[illegible]

Plank.—See "Plank."

—Same as "Felloe."

Plank.—Same as "Felloe Plank." See "Plank."

—An unwoven fabric of short hair or wool matted together by [illegible]. Used for waterproofing by applying pitch.

le Joint.—See "Joint."

le Screw.—See "Screw."

—A guard for protection. Vertical timbers, piles, etc., to protect vessels from striking, rubbing, and scarring piers.

r Pile.—See "Pile."

or Fibre.—The longitudinal filament of a body.

treme Fibre.—The fibre which is most remote from the neutral axis.

urated Fibre.—A hard, thick, dense, fibrous material used for insulation in electrical apparatus.

canized Fibre.—A vegetable fibre saturated and coated with a metallic chloride giving the material toughness and strength.

Stress.—See "Stress."

—Containing or consisting of fibres.

Fracture.—See "Fracture."

Iron.—See "Iron."

book.—A book containing any field records.

Rivet.—See "Rivet."

Work.—See "Work."

—The character or quality of steel as exhibited by its fracture when the grains are very coarse and bright.

y Steel.—See "Steel."

re-eight Knot.—See "Knot."

—A collection of papers arranged in order. A receptacle for holding papers. A rough steel hand-tool used for reducing or smoothing metals, wood, and other resistant materials. To cut or wear away a portion of an object by the application of a filing tool.

Bastard File.—A file having an intermediate surface between that of a smooth and a rough file.

nt File.—A file terminating in a blunt end.

Circular File.—A small file having a circular cross section.

Double End File.—A file having both ends cut for service.

Flat File.—A thin file flat on the two opposite faces.

Flat Wood File.—A coarse-cut, flat file for using on wood.

Half-round Bastard File.—A medium cut file having a semi-circular cross section.

Half-round Wood File.—Similar to a half-round bastard file, excepting that it is coarser cut and is used exclusively on wood.

int File.—A small round file of uniform section throughout its length.

tail File.—A small, circular, tapering file which resembles a rat's tail.

Square File.—Any file having a square cross section.

r File.—A file having a tapering body.

angular File.—Any file having a triangular cross section.

—To occupy with material so as to leave no space empty. An embankment behind an abutment. Any railroad embankment.

—A plate the sole function of which is to fill up space. Anything that serves to fill up a vacancy.

Filler.—A ring placed on a pin between connecting members to keep them in position.

—See "Plate."

Fillet.—A plain, narrow, flat moulding in a cornice or a corner. The rounding of a sharp corner.

Filling.—The material in an embankment or that put back into an excavation.

Back-filling.—Material put back into an excavation around a pier, pedestal, or abutment.

Filling Pile.—See "Pile."

Fin.—A thin projection on a surface of a casting caused by the imperfect contact of the two moulding flasks each containing a part of the mould. A small, thin projection on the rolled surface of any metal, especially at the edges thereof.

Final Set.—See "Set."

Final Set of Cement.—See "Set."

Fineness.—The relative size of the particles of cement, sand, or other materials.

Fine-pointed Dressing.—See "Dressing."

Fine Sand.—See "Sand."

Finish.—The condition of a surface after the final work upon it has been performed. To complete anything.

Cement Finish.—A finish made by using a cement coating.

Float Finish.—A finish on cement work made by floating grout over the surface with a straight edge.

Ground Finish.—A finish made on an object by grinding.

Indented Finish.—A finish made on cement work by running an indentation roller over it while soft.

Machine Finish.—A finish on metalwork made by turning in a lathe or planing in a machine.

Planed Finish.—A finish produced by planing.

Rough Finish.—The finish which is left by the original forms, moulds, etc.

Troweled Finish.—A finish on cement work made by troweling.

Finishing Stake.—See "Stake."

Fink Truss.—See "Truss."

Fire Brick.—See "Brick."

Fireless Locomotive.—See "Locomotive."

First-class Masonry.—See "Masonry."

First Cost.—See "Cost."

Fish.—To join two beams by fastening long splice-pieces to their sides.

Fish-bellied Girder.—See "Girder."

Fish-belly.—The form taken by some girders or trusses where the bottom flange or chord is convex downward. To swell downward.

Fishbolt.—See "Bolt."

Fisherman's Bend.—A knot. See "Knot."

Fishing.—The act of uniting two parts by clamping them between two short pieces which cover the joint.

Fish Joint.—See "Joint."

Fish Plate.—Same as "Splice Bar." See "Bar."

Fitting-up.—Assembling the different members of a structure and connecting them with bolts preparatory to riveting.

Fitting-up Bolt.—See "Bolt."

Fitting-up Clamp.—See "Clamp."

Fitting-up Gang.—See "Gang."

Fixed Bridge.—See "Bridge."

Fixed Charges.—The annual expenditure, in connection with a structure, which remains the same, or nearly so, regardless of operation. Generally refers to the interest on the bonded indebtedness.

Fixed End.—The anchored end. An end of a girder or strut so firmly connected as to prevent all motion in the vicinity of the end.

—See "Lead."

Point.—Any point that is stationary or assumed to remain fixed throughout he entire discussion. The common centre of gravity of a system of bodies.

Post.—See "Post."

Span.—See "Span."

e.—One of the principal longitudinal members of a girder which resist tension or compression, also sometimes called the upper and lower chords of a beam. A projecting edge, rim, or rib on anything.

heel Flange.—The lip or projection on the face of a wheel acting as a guide or restraint.

e Angles.—See "Angle."

e Coupling.—See "Coupling."

e Joint.—See "Joint."

e Plate.—See "Plate."

e Rail.—See "Rail."

e Splice.—See "Splice."

e Stress.—See "Stress."

e Union.—See "Union."

(of gear tooth).—See "Tooth."

Valve.—Same as "Check Valve." See "Valve."

ing Angle.—See "Angle."

ing Point.—The temperature at which escaping gas will ignite momentarily.

ings.—Broad strips of sheet metal used at the joints of a wall so as to lap over gutters, chimneys, etc. Also strips worked in under the slates or shingles around dormers, chimneys, and any rising part, to prevent leaking.

ks.—The upper and lower parts of a box which contain the mould into which molten metal is poured.

t.—The broad side of anything. Any rectangular iron or steel bar having a greater width than thickness. A level stretch of ground near a stream.

Arch.—See "Arch."

Dolly.—See "Dolly."

File.—See "File."

-head.—A rivet or bolt head that has been flattened.

-head Rivet.—See "Rivet."

Rasp.—See "Rasp."

Reamer.—See "Reamer."

Rope Pulley.—See "Pulley."

Scale.—See "Scale."

ing.—Causing painting to have a dead or dull finish instead of a glossy one by using turpentine instead of oil in the last coat.

Wood File.—See "File."

t.—To swing into place by means of a horizontal, subsidiary tackle, a bridge member when it has to be picked up by the main tackle from a position not directly under the support of the main tackle.

ing Tackle.—See "Tackle."

Bond.—See "Bond."

Brick.—See "Brick."

Knot.—See "Knot."

Loop.—See "Knot."

Joint.—See "Joint."

Bending.

Theory of Flexure.—The theory accounting for the stress intensity and ion in a beam subjected to transverse loading on the assumptions that is slight, that the elastic limit is not exceeded in any part of the beam,

[illegible]—See "[illegible]."

[illegible] Surface.—A surface made [illegible] with a smooth board.

[illegible]—A term used for a bridgeman [illegible] moves to another.

Float Finish.—See "Finish."

Floating Bridge.—Same as a "Boat Bridge."

Floating Derrick.—See "Derrick."

Floating Pile Driver.—See "Pile Driver."

Flogging Hammer.—See "Hammer."

Floor or Flooring.—That part of a bridge which

Ballasted Floor.—A bridge floor under a [illegible] with ties embedded therein.

Buckle Plate Floor.—In bridgework a floor system [illegible] for supporting pavement.

Cement Floor.—A floor having a grouted [illegible]

Concrete Floor.—A floor made of concrete.

Corrugated Steel Floor.—A floor system composed

Reinforced Concrete Floor.—A floor composed of

Solid Steel Floor.—A floor composed of steel [illegible] buckled, or trough plates.

Suspended Floor.—A floor attached to suspension

Tile Floor.—A floor laid with tile.

Timber Floor.—A floor consisting of timber joists and

Trough Plate Floor.—A bridge floor system composed

Wearing Floor.—A floor exposed to the traffic. [illegible] of a double plank floor.

Floor-beam.—A transverse beam or girder placed at [illegible] support the stringers which carry the floor.

End Floor-beam.—The floor-beam at the end of a

Intermediate Floor-beam.—Any floor-beam between

Floor-beam Concentration.—See "Concentration."

Floor Bolt.—See "Bolt."

Floor Girder.—See "Girder."

Flooring.—Same as "Floor," *q.v.* Also planks used in

Dressed and Matched Flooring.—Planks that are dressed [illegible] *i.e.*, tongued and grooved.

Floor Plank.—See "Plank."

Floor Space.—The area of a floor.

Floor Spike.—See "Spike."

Floor System.—The system of members in a bridge [illegible] its load.

Flour of Lime.—See "Lime."

Flow (of liquids).—A continuous passing of a liquid. A

[illegible]

[illegible] pressure.

—A moderate-size ditch or channel for conducting water.

h.—To make one part even or level with another. To wash by turning on a sudden dash of water.

h (with mortar).—Same as to float, *q.v.* Also to throw rich grout onto the [illegible] before pouring new concrete on.

h Joint.—See "Joint."

ted.—Grooved or furrowed.

ted Drill.—See "Drill."

ted Reamer.—See "Reamer."

ing.—The system of longitudinal grooves in a pilaster or column.

x.—To convert to a liquid state by means of heat; to melt. A substance that promotes the fusion of minerals or metals. The process of melting. Fusion.

ing Buttress.—See "Buttress."

ing Falsework.—See "Falsework."

ing Level.—See "Level."

Wheel.—See "Wheel."

ding Bridge.—Same as "Jack-knife Bridge." See "Bridge."

iated Granite.—See "Granite."

ower.—Any cog that is driven by another. A temporary piece of pile or timber set above a pile that is to be driven below the leads of the pile-driver.

Block.—See "Block."

Bridge.—See "Bridge."

Hammer.—See "Hammer."

ting.—The spreading course at the base of a foundation.

Column Footing.—A footing, or spread base, under a column.

Pier Footing.—A footing under a pier.

ting Beam.—See "Beam."

ing Course.—See "Course."

-pound.—A unit of work equal to that involved by the raising of a weight of one pound one foot high. Also used as a unit of bending moment in which case it is equal to a force of one pound multiplied by a lever arm of one foot. This latter unit is called by some authorities "pound-foot," *q.v.*

-pound Second.—A unit of power, or rate of doing work, equal to raising one pound one foot high in one second.

-ton.—See "Ton."

-walk.—A sidewalk for pedestrians.

e.—That which moves or tends to move matter. The action between two bodies either causing or tending to cause change in their relative rest or motion.

Centrifugal Force.—The reaction of a body, due to its inertia, against that force which is causing it to deviate from a straight-line motion and to travel in a curved path. A fictitious force apparently balancing the central force.

Centripetal Force.—A force pulling a body toward the centre of rotation.

Concurrent Forces.—Forces in which the lines of action intersect in a common point.

pulsive Force.—A force which produces a finite change of motion in an indefinitely brief time.

rnal Force.—Same as "Internal Stress." See "Stress.'

allelogram of Forces.—See "Parallelogram of Forces"

ltant Force—Same as "Resultant," *q.v.*

Diagram.—See "Diagram."

—See "Polygon."

See "Pump."

—See "Triangle."

[illegible]

[illegible] Foreman.—A foreman [illegible]

[illegible].—A foreman under the [illegible] one gang of men.

Foresight.—A forward observation made with [illegible] in the front which is sighted upon from [illegible] the instrument.

Forge.—To work wrought iron into shape by heat [illegible] into required form. The apparatus [illegible] being worked.

Blacksmith's Forge.—A small forge used by [illegible]

Rivet Forge.—A small forge used for heating [illegible]

Forge Hammer.—See "Hammer."

Forge Iron.—See "Iron."

Forge Pig.—See "Pig."

Forge Shop.—A shop in which forgings are made [illegible]

Forging.—The process of welding metal or that of [illegible] hammering. Also the article made by [illegible]

Drop Forging.—A forging produced by a drop [illegible]

Forked Drill.—See "Drill."

Forked-end.—The end of a bar, wrench, truss [illegible] two or more projecting parts like the tines of a [illegible]

Forked Wrench.—See "Wrench."

Form.—A shape or mould. A figure described by [illegible] wooden or metallic structure for giving [illegible]

Former.—A device for giving a particular shape to [illegible]

Forming Iron.—A blacksmith's swage block.

Formula.—Any general equation; a rule or principle [illegible]

Empirical Formula.—A formula pertaining to or [illegible] ments.

Rational Formula.—A formula derived from fund[illegible]

Straight-line Formula.—One of the several types [illegible] resistance of columns. In this type the relation of [illegible] its length divided by its least radius of gyration can [illegible] line.

Foundation.—That portion of a structure, usually below [illegible] which distributes the pressure upon its support. [illegible] material itself.

Pile Foundation.—A foundation formed in soft soil by [illegible] depth which will give them the requisite bearing [illegible]

Spread Foundation.—Similar to "Footing," *q.v.* Also [illegible] cylinders for piers; the spreading being done after the [illegible]

Foundation Bed.—See "Bed."

Foundation Pile.—See "Pile."

Foundation Pit.—See "Pit."

Foundry.—An establishment or plant where metals are [illegible]

Iron Foundry.—The place where iron castings are made [illegible]

Fox Bolt.—See "Bolt."

Foxtail.—A thin wedge inserted into a slit at the lower [illegible] pin is driven down the wedge enters it and causes it [illegible] firmly.

—To break or split. A partial or total separation of parts of a continuous solid body under the action of force.

Angular Fracture.—A sharp-pointed or sharp-cornered fracture.

Columnar Fracture.—A cleavage into columns shown in the surfaces of the fracture.

Conchoidal Fracture.—A fracture showing shell-shaped depressions.

Crystalline Fracture.—A fracture leaving small crystals showing.

Cup Fracture.—A fracture in the shape of a cup.

Fibrous Fracture.—A fracture that shows the broken ends of fibres.

Granular Fracture.—A fracture showing grains or granules on its surface.

Irregular Fracture.—An extremely uneven fracture.

Silky Fracture.—A fracture showing a glossy surface.

Smooth Fracture.—A fracture either without any projections or having very few of them.

Fracture Section.—See "Section."

Frame.—The sustaining parts of a structure. Framework. An instrument for holding or supporting things, as the frame of a hack-saw.

Bed Frame.—The frame on which the bed of an engine rests.

Cross Frame.—A transverse bracing frame between stringers. Also termed a "Buck Brace."

Hand Frame.—An iron barrow used in a foundry.

Printing Frame.—A frame with a padded cloth back and a glass front, used in the process of making blue prints.

Roller Frame.—Same as "Roller Box." See "Box."

Wheel Frame.—A framework supporting a wheel or wheels.

med Bent.—See "Bent."

med Bridge.—See "Bridge."

med Girders.—See "Girders."

e Diagram.—See "Diagram."

med Trestle.—See "Trestle."

e Pulley.—See "Pulley."

ework.—An open structure supporting anything.

ing.—The cutting and shaping of timbers which fit together to form a framework.

ing Chisel.—See "Chisel."

body Method.—A method that consists in conceiving a body or a portion thereof as isolated from all others which act in any way upon it, those actions being introduced as so many forces, known or unknown, in amount and position.

end.—The expansion end, or the end that is free to move or to rotate.

Lime.—See "Lime."

Process.—A process for freezing earth that is thoroughly saturated with water, by means of a freezing mixture forced into tubes by an ice-making machine. When the wall of earth is frozen sufficiently to withstand the external pressure, the excavation then can proceed as in dry ground.

Locomotive.—See "Locomotive."

—The resistance to the relative motion sliding or rolling, of surfaces of bodies in contact.

of Friction.—Same as "Angle of Repose," *q.v.*

of Friction.—A numerical quantity equal to the ratio of the frictional resistance to the normal pressure between the bodies; or, in other words, to the tangent of the angle of repose.

Friction.—The resistance to rotation offered by the surface of the bearing revolving axle or journal.

—The resistance offered by a surface to another surface rolling

[illegible]—See "Drum."

[illegible]—See "Gear."

[illegible] Hammer.—See "Hammer."

[illegible] Pulley.—See "Pulley."

[illegible] Roller.—See "Roller."

[illegible] Washer.—See "Washer."

[illegible] Wheel.—A form of slip coupling [illegible] are sudden and great, as in dredges. [illegible]

Frieze.—The middle division of an entablature, [illegible] below the cornice.

Frog.—A contrivance built of four pieces of [illegible] for passing the flanges of car-wheels across [illegible]

Front Batter.—See "Batter."

Frustum.—That which is left of a solid, [illegible] the upper part, including the vertex, by a [illegible] base.

Fulcrum.—A pivot point or support. The [illegible]

Fuller.—A special block with a rounding edge [illegible] metals.

Full Splice.—See "Splice."

Function.—A mathematical quantity which has [illegible] of other quantities that are called the arguments, [illegible] function.

Trigonometric Functions.—Certain functions of [illegible] such as sine, cosine, tangent, or their several [illegible]

Funicular Polygon.—Same as "Equilibrium Polygon."

Furnace.—A structure in which a fire is maintained [illegible] or ores.

Acid Open-hearth Furnace.—A furnace used in the [illegible] hearth Steel. See "Steel."

Annealing Furnace.—A furnace in which the process [illegible]

Asphalt Furnace.—A portable furnace in which [illegible] in roofing or paving.

Assay Furnace.—A small, simple form of furnace [illegible] cupels.

Balling Furnace.—A furnace in which the fagots of [illegible] preparatory to working.

Basic Open-hearth Furnace.—A furnace used in the [illegible] hearth Steel. See "Steel."

Bessemer Furnace.—A furnace mounted on trunnions [illegible] direction and having air-blast connections through [illegible] verting pig iron into Bessemer steel by a process of [illegible]

Blast Furnace.—A furnace used in smelting iron ore.

[illegible] Furnace.—A furnace used in the process of cementation. See "Cementation."

[illegible] Furnace.—A general term for any iron working furnace, such as a blast furnace, puddling furnace, etc.

Open-hearth Furnace.—In steel manufacture, a regenerative, reverberatory furnace in which the hearth is exposed to the action of the flame.

Puddling Furnace.—A reverberatory furnace in which cast iron is converted into wrought iron.

Regenerative Furnace.—An open-hearth furnace using producer gas as a fuel, but so arranged that the gas is conducted to the hearth area through a passage-way filled with red-hot bricks stacked to form an open checkerwork. As the hot gas enters the furnace, it is mingled, in proper proportions, with air similarly heated, so that complete combustion is produced. The escaping hot gases are conducted through a second passage-way filled with bricks, which absorb much of the waste heat. The two passage-ways are used alternately to heat the producer gas which is fed into the furnace.

Reverberatory Furnace.—A furnace having a vaulted ceiling which deflects the flame and heat toward the hearth where the ore is to be fused, the fuel being separated from the ore by a compartment.

Rotary Furnace.—A form of puddling furnace in which the hearth is made to rotate in a vertical or a horizontal plane in order to assist in removing the carbon.

[illegible]ring.—A piece placed upon another that is too low, merely to bring its upper surface to a required level.

[illegible]—To melt. A slow burning match used to ignite an explosive, such as powder or dynamite. By burning some time it enables the man lighting the fuse to get out of the way before the explosion occurs.

Percussion Fuse.—A detonating fuse which is exploded by impact.

[illegible]—Same as "Fuse," *q.v.*

G

[illegible]—The sharp point on a steel rod, spear, pike pole, or stake.

[illegible]dding.—In quarrying, the drilling of holes for taking out dimension stone

[illegible]dding-machine.—The drilling machine used in gadding.

[illegible] Steel.—See "Steel."

[illegible]—A steel or iron hook without a barb, provided with a wooden handle, used to haul in objects that have fallen overboard from a vessel. To hook or engage with a gaff.

[illegible] Hook.—Same as "Gaff."

[illegible]—Same as "Gauge," *q.v.*

[illegible]er.—A moulder's tool, used to lift sand from a flask in moulding.

[illegible] Press.—See "Press."

[illegible] Process.—The process of bending structural shapes in a gag press.

[illegible]—A beveled shoulder on the end of a mortised brace for the purpose of giving it additional resistance to the shoulder. To make progress. To make grooves or mortises in timber.

[illegible]—The act of cutting grooves or mortises in timbers.

[illegible] Machine.—An apparatus that does gaining.

[illegible]—An English unit of capacity for dry or liquid measure containing 231 cubic inches.

[illegible]—A set of timbers consisting of two upright posts, or props, and a bar or cap, [illegible] across their tops and cantilevered out from the posts. Its function is the [illegible] of objects—generally temporarily.

[illegible]—The frame of a "Gallows," *q.v.*

[illegible]

[illegible]

[illegible]

Gang.—A combination of [illegible]
so contrived as to be made to act [illegible]

[illegible] Gang.—A crew of [illegible]
the bridge site.

Derrick Gang.—A gang of [illegible]

Erection Gang.—A gang that does the [illegible]

Fitting-up Gang.—A gang which does the [illegible]

Riveting Gang.—A gang that does the [illegible]

Gang Drill.—See "Drill."

Gang Plank.—See "Plank."

Gang Punch.—See "Punch."

Gangway.—A temporary passage used during

Gantry or Gauntry.—A frame or scaffold which

Gantry Crane.—See "Crane."

Gantry Traveler.—See "Traveler."

Gas Engine.—See "Engine."

Gasket.—Rope-yarn, hemp, rubber, rainbow
water pipes and steam pipes, in pistons of
to obtain a tight joint.

Gasoline Engine.—See "Engine."

Gas Pipe.—See "Pipe."

Gate.—A movable barrier. In casting, one of the
the sand for the molten metal to flow
of metal cast in the gate. A ridge in a casting

Automatic Gate.—In bridgework, a steel, timber
matically.

Gate Block.—Same as "Snatch Block." See "Block."

Gate Valve.—See "Valve."

Gauge or Gage.—A standard of measure. An instrument
capacity, quantities, or forces. A standard of
rivet lines in structural shapes. The distance between
of the rails in a track.

Air Gauge.—A dial on an air machine which records
usually in pounds per square inch.

Drill Gauge.—A gauge for determining the angle of a

Hand Gauge.—The ordinary wooden scratch gauge
off a line parallel to the edge of a board.

Hydraulic Gauge.—Same as "Hydraulic Indicator."

Micrometer Gauge.—Same as "Micrometer Calipers."

Plate Gauge.—An instrument for measuring the thickness

Pressure Gauge.—A gauge which indicates the pressure

Standard Gauge.—The adopted standard distance between
balls of rails in a track; equal to four feet eight and
established by agreement between all of the railroads

Steam Gauge.—An instrument for determining and indicating

Tide Gauge.—A device for indicating, and in some
the tide at any time.

Track Gauge.—The distance between the treads of the
for measuring or laying off that distance.

Wire Gauge.—A tool for measuring the diameters of wire
metals, also the system of sizes and numbers for wire

Gauge Glass.—The exposed glass tube, connected with a boiler, which shows the height of water in the said boiler.

Gauge Length.—See "Length."

Gauge Pile.—See "Pile."

Gauging.—Making measurements. The act of judging distances, heights, etc., either by eye or by instruments. Ascertaining the volume of discharge of a stream.

Gauntry.—Same as "Gantry," *q.v.*

Gear.—A wheel having teeth on its periphery or face. A piece of mechanism for transmitting motion. To fit with gears. To connect one part of a mechanism at will with another.

Bevel Gears.—Gears having teeth arranged around the convex surface of a conical wheel in the direction of a radial plane passing through the axis of the cone.

Cast Gears.—Gears made by casting and not cut.

Chain Gear.—A device for the transmission of motion by means of a chain engaging the cogs or sprockets of a wheel.

Conical Gear.—Same as "Bevel Gear," *q.v.*

Cut Gears.—Gears in which the teeth are cut by a machine so as to mesh accurately, in contra-distinction to cast gears in which the teeth are not machined.

Differential Gears.—A combination of gears by which a differential motion is produced.

Driving Gears.—Those gears which drive other gears or mechanisms.

Eccentric Gear.—A gear wheel mounted with shaft out of centre.

Friction Gear.—A toothless gear wheel transmitting power by means of friction between its periphery and that of the wheel in contact.

Hand Gear.—A hand mechanism for opening the valves of a steam engine in starting it.

Idle Gear.—An intermediate gear wheel running loosely on its own axle, used to convey motion from one wheel to another, all three being upon different axles.

Knuckle-Gear.—A crude form of toothed gearing used for slow-moving machinery, such as cranes.

Locking Gear.—A mechanism which locks a movable span when closed.

Miter Gears.—A pair of beveled gears in which an element of the conical pitch surface makes an angle of forty-five degrees with the axis.

Moulded Gears.—Same as "Cast Gears," *q.v.*

Ratchet Gear.—A gear wheel having sharp-pointed teeth, non-symmetrical about a radial line, leaning away from the direction of rotation so as to engage a pawl which catches on the tooth and prevents backward motion.

Spin Gear.—Same as "Idle Gear," *q.v.*

Spiral Gear.—A gear having teeth arranged spirally, so as to mesh with a worm.

Split Gear.—A gear wheel made in halves for convenience in mounting.

Spur Gear.—A gear having teeth arranged around either the concave or convex surface of a cylindrical wheel and in the direction of a radial plane passing through the axis.

Stepped Gear.—A form of gearing in which each tooth or cog on the face of a wheel is replaced by a series of smaller teeth.

Stripping of Gears.—The tearing or shearing off of the teeth of gear wheels or portions thereof.

Worm Gear.—A gear wheel having special oblique teeth which mesh with a worm.

Geared Locomotive.—See "Locomotive."

Gearing.—A train of gear wheels. A general term for the parts of a machine or mechanism, taken collectively, which transmit motion.

Frictional Gearing.—Wheels which make rolling contact and transmit motion by the friction set up between their surfaces.

[illegible]

[illegible]—Pertaining to earth in a [illegible]

[illegible] Having the quality of [illegible]

[illegible] Arch.—See "Arch."

[illegible] Knot.—Same as a "Figure [illegible]

[illegible] Steel.—See "Steel."

[illegible] Rod.—See "Rod."

Gib.—A piece of metal in the shape of [illegible]

Gilbreth Pile.—See "Pile."

Gin.—A revolving vertical pole or column, [illegible] one or more long horizontal arms [illegible] and wind up the rope, thereby raising a [illegible]

Horse Gin.—A gin driven by one or more [illegible]

Gin Block.—See "Block."

Gin Pole.—A mast, or vertical pole, guyed [illegible] with blocks and tackle for raising weights.

Gin Pole Derrick.—See "Derrick."

Gin Tackle.—See "Tackle."

Gin Type Derrick.—See "Derrick."

Girder.—A beam or compound structure acting [illegible] verse loads which develop normal reactions [illegible]

Arched Girder.—A girder which is cut, bent, or [illegible]

Bowstring Girder.—A girder consisting of a curved [illegible] tension member arranged as a chord and [illegible] rods.

Box Girder.—A type of girder having two webs [illegible] made up of plates and angles riveted together and [illegible]

Built Girder.—A girder made up of structural plates [illegible]

Circular Girder.—A girder built in the shape of a [illegible]

Compound Girder.—Same as a "Built Girder," *q.v.*

Concrete Girder.—A girder built of concrete and [illegible]

Continuous Girder.—A girder with more than two [illegible]

Crane Girder.—A girder either stationary or movable, [illegible]

Cross Girder.—Any girder passing across a bridge [illegible] to another, and, generally, perpendicular to the truss [illegible]

Curb Girder.—A steel or reinforced concrete girder [illegible] forming the curb of a roadway.

Curved Girder.—Any girder in the shape of a curve.

Deck Girder.—One of the main girders of a deck bridge.

Deck Plate Girder.—One of the main plate girders in a [illegible]

Effective Depth of Girder.—See "Depth."

[illegible]—Any girder one end of which is allowed to [illegible]

[illegible]—A longitudinal girder at the extreme edge of a [illegible] to present a neat appearance.

Bellied Girder.—A girder having the top flange horizontal and the bottom [illegible] rved in the shape of a fish's belly.

[illegible] Girder.—Same as "Sandwich Girder," *q.v.*

Girder.—Any girder which supports a portion of the floor and its load.

ed Girder.—A girder constructed of timbers framed together.

-latticed Girder or Half-plate Latticed Girder.—A lattice girder the [illegible] which have web plates while the central portion of the web is latticed.

-through Girder.—A loose expression for a girder of a "Half-through [illegible] Span," *q.v.*

-through Latticed Girder.—A loose expression for a latticed girder of a "Half-through Span," *q.v.*

-through Plate Girder.—A loose expression for a plate girder of a "Half-through Span," *q.v.*

Beam Girder.—A girder composed of an I-Beam.

ticed Girder.—A riveted girder having the upper and lower flanges [illegible] by latticing, or by diagonal bars or angles.

itudinal Girder.—The main girder in a structure running parallel to the [illegible] line thereof.

Web Girder.—Same as "Latticed Girder."

rhead Girder.—A girder that is overhead—usually moving on an overhead track as in a traveling crane.

Girder.—A girder built of structural plates and angles.

eted Girder.—A girder built of plates and angles riveted together throughout.

dwich Girder.—A girder or beam having an iron or steel plate inserted between two wooden beams and rigidly bolted thereto.

Girder.—A built-up plate-girder with the web lying in the horizontal plane riveted to the inside of the web members of a truss to protect these members in case of derailment of trains.

ing Girder.—A girder employed to give vertical stiffness, as in the case of a suspension bridge.

Girder.—A lintel.

Girder.—A girder built in the shape of the letter T.

Girder.—Incorrectly used for a "Half-through Girder." Strictly speaking, through girder would mean a main girder of a tubular bridge. See "Half-through [illegible]"

Girder.—A girder built mainly of timber.

verse Girder.—Same as "Cross Girder," *q.v.*

ling Girder.—A girder that moves on rails.

Girder.—A latticed girder having a system of web members all inclined to the vertical.

Girder.—A girder stiffened and strengthened by means of trussing, *q.v.*

Girder.—A girder having a latticed web system forming with the flanges [illegible] in all essential features.

Girder.—A fish-bellied girder that is used for a turn-table.

Girder.—A latticed triangular girder in which all the triangles are equilateral. days any triangular girder is spoken of as a Warren Girder.

[illegible]—See "Bridge."

[illegible]—See "Dog."

[illegible]—See "Guard-rail."

[illegible]—Same as "Girder Dog."

[illegible]

Glacis.—An easy slope of earth

Gland.—A stuffing box around the
shafts.

Glass Gutter.—See "Gutter."

Glazed Iron.—See "Iron."

Globe Valve.—See "Valve."

Gneiss.—A rock which contains
the mica disposed in parallel planes,
into thick slabs.

Go-devil.—A rough sled for hauling
dynamite cartridges in holes. A

Gag Press.—Same as "Gag Press." See

Goose-neck.—An iron or steel hook fitted
attachment to a clamp or an eye bolt.
from a caisson by means of compressed
A flexible coupling.

Goose-neck Dolly.—See "Dolly."

Gordon's Formula.—A column formula.

$$p = \frac{s}{1 + a\frac{l^2}{r^2}}$$

where

p = the allowable unit stress for the
s = the allowable unit stress for
a = a constant depending on end
l = the unsupported length of the
r = the least radius of gyration in
in which flexure takes place.

Gouge.—To scoop out. A chisel with a longitudinal
stone, or metal.

Hand Gouge.—A gouge that is operated by

Handle Gouge.—A gouge in the form of a
used to cut metal.

Governor.—An apparatus consisting of two balls or
an upright revolving axis, so arranged as to
and in so doing to raise the radial arms and

Grab.—A mechanical device for gripping an object,

Grab Bucket.—See "Bucket."

Grade.—The degree of inclination from the horizontal
To arrange in order according to size or quality.
a hill, especially by hydraulicking.

Break in Grade.—That point where the grade

Sub Grade.—The bottom surface of the ballast or

Grade Crossing.—See "Crossing."

Grade Line.—See "Line."

Grade Plug.—A plug, generally of wood, driven down
elevation of the cutting at the place where the

Grade Point.—A point of established elevation to

Grade Stake.—See "Stake."

ent.—The rate of grade, measured by the rise or fall in one hundred feet, and nerally expressed as so much per cent.

ater.—A small screw, with graduated head attached to an engineer's transit r turning off small vertical angles. Used in fixing grades.

—The smallest unit of weight of the English system. The texture of material.

e fork of a river, or a place at which two streams unite. A tine, prong, or spike.

he arrangement and direction of the fibres in wood.

e.—A rock composed of mica, feldspar, and quarts with a thoroughly crystalline, anular texture.

d Granite, or Bastard Granite, or Foliated Granite.—Same as "Gneiss."

e-chips.—The chippings left from granite after dressing; the crushings of granite wls.

Masonry.—See "Masonry."

Screenings.—See "Screenings."

id.—Small chippings of any granite mixed with cement forming concrete for ewalks, curbs, etc. Nowadays, any concrete composed of flinty, hard materials xed with sand and cement is erroneously termed granitoid.

r.—Containing or bearing grains or granules.

r Fracture.—See "Fracture."

r Structure.—See "Structure."

c Diagram.—See "Diagram."

ics.—The method or process of solving problems by means of drawing lines.

c Statics.—See "Statics."

ite.—A form of carbon. Used for lead pencils, lubrication of machinery, the ubbing surfaces of wood, and as a conductor in electrical construction. Also mployed as a pigment for paints used in structural steel work.

ck Lead Graphite or Plumbago Graphite.—Same as "Graphite," *q.v.*

ite Paint.—See "Paint."

e or Grapnel.—A mechanical device having six arms shaped like an anchor, sed to grasp things in deep water.

r's Cement.—See "Cement."

e.—To cast and drag with a grapnel.

ing Iron.—An instrument having several iron or steel claws for holding fast to hings.

l.—Worn, round fragments of rock, occurring in natural deposits, small enough pass through a two and one-half inch iron ring and large enough to be retained a No. 10 screen.

Concrete.—See "Concrete."

Sieve.—See "Sieve."

er.—An instrument for determining the centre of gravity of a body.

—The force of attraction exerted by the earth on bodies near it. Weight ntra-distinguished from mass.

of Gravity.—A line passing through the centres of gravity of successive elemental ions of a body.

of Gravity.—That point in a body about which the weights of all the various balance. It is found experimentally by balancing on a knife edge.

of Gravity.—The line along which the centre of gravity would move, if the body free to fall.

of Gravity.—Any vertical plane passing through the centre of gravity of a

Gravity.—The ratio of the weight of a unit volume of a substance to the weight volume of the standard substance, such as water.

"Column."

"Iron."

[illegible]

[illegible] See "Bolt."

[illegible]

[illegible] each other at right angles. A [illegible] stream to retard or deflect the

Groined Arch.—See "Arch."

Groove.—A small channel. A cut in

Chamfered Groove.—A triangular

Oil Groove.—A groove cut in the [illegible] ing of oil over the journal.

Grooved Rail.—Same as "Girder

Groove Joint.—See "Joint."

Groover.—A cement finisher's hand tool for

Gross Section.—See "Section."

Ground Finish.—See "Finish."

Ground-hog.—A laborer who digs in the [illegible] contradistinction to a "Sand-hog," who

Ground Joint.—See "Joint."

Ground Line.—See "Line."

Grout.—A mortar composed of sand, [illegible] that it can easily be poured. To pour grout

Portland Cement Grout.—Grout in which

Grouting.—The pouring of grout.

Grubbing.—The removing of stumps and roots from [illegible] to railway embankments.

Guard.—Any part of an appliance, structure, or [illegible] injuring of persons, vehicles, etc. A fender.

Bridge Guard.—A timber or other construction, [illegible] sunk deep into the ground near the end of a bridge [illegible] by either derailed cars or badly shifted loading.

Cattle Guard.—A device consisting usually of [illegible] a railroad track to prevent stock from getting on

Dust Guard.—Steel plates placed around rockers, [illegible] out dirt and dust. A thin piece of wood, leather [illegible] to keep out the dust from the bearings, and to [illegible] from the box.

Hub Guard.—An angle, plate, etc., on corners of [illegible] materials, where vehicular traffic passes, to [illegible] rubbing of wheel hubs.

Ice Guard.—A fender placed at the up-stream end [illegible] or else to break up the large cakes into small pieces

Guard.

Rerailing Guard.—A casting or device attached to the rails near the end of a railway structure so that, if an engine or car is derailed, it will run back on the track.

Rope Guard.—A mechanical device for ropes running over sheaves or through pulley-blocks.

Wheel Guard.—A timber or iron placed on the side of the roadway of a bridge to prevent the wheel hubs from striking the truss or the hand railing.

Guard-rail.—Same as "Felly Plank," *q.v.* Also the inner steel rails between the main rails of a railway track.

Girder Guard-rail.—A street car rail having a ball wider than the ordinary rail and with a slot in it to allow the flanges of the car wheels to roll therein. This rail is often placed on curves.

Inner Guard-rails.—Guard-rails placed between the gauge lines of a car track.

Outer Guard-rails.—Guard-rails placed outside the rails of a car track.

Guard Timber.—A guard-rail made of a timber, usually dapped over the ties for railway bridges.

Gudgeon.—That part of a shaft resting in the bearing, especially when made of a separate piece. A metallic journal-piece let into the end of a wooden shaft. A metallic pin used for securing together two blocks or slabs of stone. A cramp.

Gudgeon Pin.—Same as "Gudgeon," *q.v.*

Guide.—Any apparatus or contrivance intended to direct or to keep to a desired course or motion.

Hammer Guides.—The guides for holding in proper course the motion of a hammer.

Guide Bar.—See "Bar."

Guide Block.—Same as "Guide Bar," *q.v.*

Guide Chair.—A device resembling a chair, used as a guide.

Guide Frame.—A framework used as a guide.

Guide Pile.—See "Pile."

Guide Pin.—See "Pin."

Guide Pulley.—See "Pulley."

Guide Rail.—See "Rail."

Guide Roller.—See "Roller."

Guide Ropes.—See "Ropes."

Guide Screw.—See "Screw."

Guide Tube.—See "Tube."

Guide Wedge.—See "Wedge."

Guide-yoke.—A yoke-shaped piece for supporting the guides in a machine or engine.

Gun.—A device for discharging missles through a tube. Also a hammer operated by air.

Air Gun.—A pneumatic riveting hammer.

Blow Gun.—A barrel or pipe through which material is blown.

Cement Gun.—A barrel or nozzle through which grout is forced by compressed air.

Pneumatic Riveting Gun.—A rivet hammer operated by compressed air.

Riveting Gun.—A riveting hammer.

Gun Metal.—Same as "Bronze," *q.v.*

Gunnel or **Gunwale.**—The upper edge of a boat's side.

Gunnysack.—A coarse sack of jute or hemp for various uses, such as holding cement in transit or to contain sand for revetment.

Gunpowder.—An explosive mixture of nitre, charcoal, and sulphur.

Gunpowder Pile Driver.—See "Pile Driver."

Gunwale.—Same as "Gunnel," *q.v.*

Gusset.—An angular piece of iron or steel, or a steel plate fastened to angles, channels, or the members of a structure to give strength and stiffness to them, or to connect them to the construction.

Gusset Plate.—See "Plate."

Guy.—A line for bracing the top of a pole, derrick, or any other similar apparatus.

Guy Derrick.—See "Derrick."

Guy Line.—Same as "Guy," *q.v.*

Guy Ring.—See "Ring."

Guy Rope.—See "Rope."

Gypsum.—A chalk formation containing the native hydrous sulphate of calcium.

Gyrate.—To revolve about an axis or a point.

Gyration.—The act of revolving or gyrating.

Centre of Gyration.—A point in a revolving body such that if all the matter of the said body could be collected there, the body would continue to revolve with the same energy as when its parts were in their original places.

Radius of Gyration.—The radius of gyration of a body about a given axis is the distance from the axis of rotation to the centre of gyration, and is equal to the square root of the mean of all the squares of the distances from the axis of rotation to all the points in the body.

Gyroscope.—An instrument consisting of a fly-wheel so mounted that its axis is free to turn in any direction. It is used to illustrate the dynamics of rotating bodies.

H

Hacked Bolt.—See "Bolt."

Hacksaw.—See "Saw."

Haft.—A handle for a cutting tool. To supply with a handle.

Half-and-half Joint.—See "Joint."

Half-hitch Knot.—See "Knot."

Half-latticed Girder.—See "Girder."

Half-plate Latticed Girder.—See "Girder."

Half-round Bastard File.—See "File."

Half-round Rasp.—See "Rasp."

Half-round Wood File.—See "File."

Half-through Plate Girder.—See "Girder."

Half-through Span.—See "Span."

Half-through Truss.—See "Truss."

Halving.—Notching together two timbers which cross each other, so deeply that the joint thickness shall equal only that of one whole timber.

Halving Joint.—See "Joint."

Hammer.—A hand tool consisting of a solid head of metal, wood, or stone set crosswise on a handle. Used for beating, breaking, or driving. The part of a pile driver or of a steam hammer which strikes the blow. To beat or to drive.

Air Hammer.—A machine hammer driven by compressed air, as an air riveting hammer.

Axe Hammer.—A mason's hand tool consisting of a combined hammer and axe on a short handle.

Ballast Hammer.—A double-faced, long-handled, hand-hammer used in tamping ballast under and around ties.

Blocking Hammer.—A hand hammer which has a head that is diamond shaped.

Bricklayer's Hammer.—A hammer having a bent peen, used in brick work.

Bush Hammer.—A mason's finishing hammer having regular rows of points or projections on its faces.

Bust Hammer.—A hammer, used in riveting work, having a rivet buster on one end of the head and a hammer on the other end.

Claw Hammer.—A carpenter's hand hammer having a poll on one end of the head and a claw on the other.

ammer.

Cleveland Hammer.—One of the numerous makes of air riveting hammers.

Clipping Hammer.—A chisel-edged hammer used for clipping stone, concrete, etc. Nowadays air hammers are so arranged that they can quickly be converted into clipping hammers. .

Double-faced Hammer.—A forging apparatus for striking on opposite sides, as in case of a bloom.

Drop Hammer.—A heavy weight, working in guides, which is raised by means of a rope or cable and then allowed to drop.

Duplex Hammer.—Same as "Double Faced Hammer," *q.v.*

Electric Hammer.—An electrical apparatus for working a rock drill.

Engineer's Hammer.—Usually a two faced cylindrical hand hammer, though sometimes having a cylindrical poll and a triangular peen.

Flogging Hammer.—A very large hammer used with a flogging chisel for chipping iron castings.

Foot Hammer.—A machine hammer operated by a treadle.

Forge Hammer.—A hammer used for breaking and trimming rocks.

Friction Hammer.—A drop-hammer raised by the friction of rollers.

Hand Hammer.—Any hammer which is used by hand.

Helve Hammer.—A trip-hammer.

Holding-up Hammer.—A heavy engineer's hammer on a long handle, used in times past for bucking up rivets.

Lift Hammer.—A drop-hammer of a pile driver.

Machinist's Hammer.—A hammer with a round, flat face and a cross peen.

Mason's Hammer.—A square-faced hammer with a peen in line with the handle.

Nasmyth's Steam Hammer.—The earliest form of steam hammer—invented by Nasmyth and Bourdon. Its essentials are a steam cylinder, piston, piston rod carrying a heavy weight for hammer, pile cap and a frame of two I-beams holding the parts together.

Paane Hammer, or **Pane Hammer.**—Same as "Peen Hammer," *q.v.*

Patent Hammer.—A stone-mason's hammer having knife-like ridges on its face, used for dressing stone.

Pean Hammer.—Same as "Peen Hammer," *q.v.*

Peen Hammer.—A hammer having a peen on one or both faces. See "Peen."

Pein Hammer, or **Pene Hammer.**—Same as "Peen Hammer," *q.v.*

Pile-Driver Hammer, or **Pile Hammer.**—A drop hammer or a steam hammer used in driving piles.

Plow Hammer.—Same as "Engineer's Hammer," *q.v.*

Pneumatic Hammer.—A hammer operated by compressed air.

Power Hammer.—A hammer used for forging work.

Raising Hammer.—A hammer used for deeply dishing metal plates.

Rivet Hammer.—A pneumatic or hand hammer for driving rivets. Also a light engineer's hammer for testing the tightness of rivets after driving.

Scabbing Hammer or **Scaling Hammer.**—A hammer used for loosening and removing scale from steam boilers.

Sledge Hammer.—A medium-sized head of a sledge mounted on a short, thick handle. See "Sledge."

Slogging Hammer.—A very heavy hammer-head on a long handle used in past times for the hand-driving of rivets.

Spalling Hammer.—A heavy axe-like hammer used for roughly dressing stones.

Stamping Hammer.—A small hand hammer having the initials of the firm's name on the pointed end, used by timber inspectors and the like to stamp material which has been inspected and accepted.

[illegible]

[illegible] used to [illegible]

[illegible]

Welding Hammer.—A [illegible]

Wrench Hammer.—See "Wrench."

Hammer Axe.—Same as "Axe Ham

Hammer Beam.—See "Beam."

Hammer Dressing.—See "Dressing."

Hammered Head.—A head formed on the

Hammer Guides.—See "Guide."

Hammer-hardened.—Hardened by a proces

Hammer Head.—See "Head."

Hammer-mark.—A mark left by the blow

Hammer-pick.—A hand tool having a ham
pick at the other.

Hammer Scale.—See "Scale."

Hammer Tongs.—See "Tongs."

Hammer-wrought.—Anything which has been

Hand Axe.—See "Axe."

Hand-book.—A book containing structural sha

Hand-brick.—See "Brick."

Hand-car.—See "Car."

Hand Drill.—See "Drill."

Hand Float.—A wooden or metal trowel. See "

Hand Frame.—See "Frame."

Hand Gauge.—See "Gauge."

Hand Gear.—See "Gear."

Hand Glass.—A reading or magnifying glass used

Hand Gouge.—See "Gouge."

Hand Hammer.—See "Hammer."

Hand-hole.—A hole in a piece of metal, wood, etc.,
inserted. Used in webs and diaphragms at
riveting in close spaces.

Hand Hook.—See "Hook."

Handle.—To direct or control by hand. That part of
be grasped by the hand.

Handle Gouge.—See "Gouge."

Handle Lock Sleeve.—See "Sleeve."

Hand Level.—See "Level."

Hand Lever.—See "Lever."

Hand Line.—See "Line."

Hand Pile Driver.—See "Pile Driver.'

Hand-power Line.—See "Line."

Hand Pump.—See "Pump."

Hand Rail.—See "Rail."

Hand-rail Cap.—See "Cap."

Hand-rail Post.—See "Post."

Hand Reamer.—See "Reamer."

Hand Riveting.—See "Riveting."

Hand-saw.—See "Saw."

Hand-spike.—See "Spike."

Hand Vise.—See "Vise."

Hand Wheel.—See "Wheel."

Hand Winch.—See "Winch."

Hand-wrought.—Worked or shaped by hand.

Hanger Plate.—See "Plate."

Hangers.—Fixtures projecting below a ceiling to support bearings for a line shaft. Also a hip-vertical or suspender of a truss. Also a tension member supporting a floor system in an arch or in a suspension bridge. A beam hanger, *q.v.*

Beam Hanger.—A rod or square bar supporting a floor-beam from a chord pin.

Spandrel Hangers.—Hangers extending from the intrados of the arch to a longitudinal beam forming part of the lower roadway.

Hanging Bridge.—Same as "Suspension Bridge," *q.v.*

Hard-burned.—Overburned, a term used in the manufacture of brick.

Hardening of Steel.—See "Steel."

Hardie.—A steel block having a wedge-shaped edge set in an anvil and used for cutting heated metals.

Hardpan.—A very compact layer or bed of mingled clay and sand or pebbles, or one of shale.

Hard Set.—Same as "Final Set." See "Set."

Hard Steel.—See "Steel."

Hardwood.—See "Wood."

Harmonic Curve.—Same as "Sine Curve." See "Curve."

Harmonic Motion.—A reciprocating, rectilinear motion in which the space described by the moving body or point varies as the sine of time angle. Also the motion described by the projection, on a diameter, of a point moving uniformly in the circumference of a circle.

Hasp.—A clasp that passes over a staple and is fastened to it by a pin or a padlock.

Hatch.—To shade drawings by equidistant parallel lines.

Crosshatching.—The method of shadowing or hatching by using two intersecting sets of parallel lines.

Haul; or **Free Haul.**—The distance within a given limit, set by the specifications, that material is hauled in construction work.

Average Haul.—The mean distance that material is to be hauled. The distance from the centre of gravity of the cut to the centre of gravity of the fill in respect to all the material moved.

Total Haul.—The total distance that a material is hauled.

Haunch.—That part of an arch between the crown and the skewback.

Hay Steel.—See "Steel."

Head.—A top, upper, or higher part or place. An enlargement resembling the head of an animal.

Bolt Head.—The enlarged end of a bolt having a square or hexagonal shape.

Button Head.—The head of a bar, bolt, or rivet having the shape of a button.

Capstan Head.—That portion of the capstan which contains the holes for receiving the ends of the capstan bars.

Chord Head.—The enlarged head of a chord bar through which the pin passes.

Dog Head.—A round headed tool, used for breaking stones.

[illegible]

[illegible]

[illegible]

Pile Head.—The top of the

off the tops of piles to

off ends.

Saddle Head.—A hollow casting

column above and to allow beams to

Welded Heads.—Heads first worked

bars.

Head-block.—A timber at the top of a pile

Header.—In timber construction, the

framed in forming openings for

and supported by two longitudinal

mediate short longitudinal beams. A

dimension perpendicular to the face of the

Blind Header.—In masonry, a header stone

Header and Stretcher Bond.—See "Bond."

Head Frame.—Same as "Gallows Frame," q.v.

Heading Chisel.—See "Chisel."

Heading Joint.—See "Joint."

Heading Tool.—See "Tool."

Head Sheaves.—See "Sheaves."

Head Valve.—See "Valve."

Head Wall.—See "Wall."

Headway or Clear-headway.—See "Clear-headway."

Heart.—The solid central part of a tree containing

Per Cent of Heart.—The ratio of the area of heart

section of timber.

Ring Heart.—A cleavage along the surface of an

the heart and the bark of a tree.

Heart Bond.—See "Bond."

Heart Cam.—See "Cam."

Heart Check.—See "Check."

Heart Shake.—See "Shake."

Heart Tie.—See "Tie."

Heart Wood.—See "Wood."

Heat.—A form of energy manifested by the motion of the

Latent Heat.—The amount of heat absorbed or li

a physical change, the temperature of the body

Heater.—An apparatus for heating, a furnace, a forge,

Heat Test (of Cement).—Same as "Boiling Test." See

Heel.—The dip of a barge. A form of moulding in

or rafter. Applied to almost anything in construction

Heel Dolly.—See "Dolly."

Helicoid.—The surface generated by a straight line

and moving parallel to itself along such axis while

Helix.—A curve of double curvature generated by a

a constant radius which moves along the axis in

Helve.—The handle of an axe.

Helve Hammer.—See "Hammer."

Hemp.—A species of plant which has tough and

ropes and cables.

Henequin Hemp.—A kind of hemp which grows in

Hemp.

Manila Hemp.—A very fine hemp grown in the Philippine Islands.

Sisal Hemp.—Same as "Henequin Hemp;" *q.v.*

Virginia Hemp.—An inferior species of hemp grown along the rivers in the Eastern United States.

Water Hemp.—Same as "Virginia Hemp," *q.v.*

Hemp Packing.—See "Packing."

Henequin Hemp.—See "Hemp."

Herring-bone.—The diagonal struts fixed at intervals between the beams of a floor to distribute the load on one beam to adjacent beams and to increase the stiffness of the beams. Also applied to a course of stone laid at an angle so that the stones in each course are placed side by side, and obliquely to the right and to the left in alternate courses.

Herring-bone Dressing.—See "Dressing."

Herring-bone Work.—See "Work."

Hewed Tie.—See "Tie."

Hexagon.—A regular six-sided figure.

Hexagonal Nut.—See "Nut."

Hick Joint.—See "Joint."

Hicky.—A purely field expression employed by bridgemen for almost any contrivance, or part of one, which lacks a specific name. Analogous to "thingumbob."

Hiding Power.—The capacity of a paint or painting material to obscure a surface beneath it.

High Bridge.—See "Bridge."

High Carbon Steel.—See "Steel."

High Steel.—See "Steel."

High Water.—See "Water."

High Water-mark.—See "Water."

Extreme High Water-mark.—See "Water."

Highway.—Formerly restricted to a way or road reserved for the use of ordinary vehicles, pedestrians, or animals, but now it is often used to mean a way or road on which an electric railway also runs.

Highway Bridge.—See "Bridge."

Hinge.—A device for connecting two pieces, so that one may turn about the other.

Joint Hinge or Strap Hinge.—A hinge having long leaves joined at their large ends.

Hinged Arch.—See "Arch."

Hinged End.—The end of a member that is connected to the rest of the structure by a device that permits of a slight rotation. In contradistinction to a fixed end.

Hinged Joint.—See "Joint."

Hinged Lift Bridge.—See "Bridge."

Hinged Pin.—See "Pin."

Hinged Plate.—See "Plate."

Hinged Post.—See "Post."

Hinge-end.—The end of a piece or member that is provided with a hinge.

Hip.—The place at which the top chord meets the batter-brace or inclined end post.

Inner Hip.—The intersection of the inner inclined end post with the top chord in the arm of a swing span.

Outer Hip.—The hip at the outer end of one of the arms of a swing span.

Hip Joint.—See "Joint."

Hip-joint Hood.—A bent tie plate or strap placed over the hip to keep water out of the joint.

Hip Knob.—A finial on the hip of a roof or between the barge boards of a gable.

Hip Roof.—A roof rising directly from the wall-plate on all four sides, and so having no gable.

[illegible]

where

P = the load.

b = width of column.

l = length of column.

Hoe.—A tool for digging, scraping, [illegible] blade set transversely to a long handle [illegible]

Shank Mortar-mixer Hoe.—A solid [illegible] blade.

Shank Street Hoe.—A hoe having a solid [illegible] hoe.

Socket Mortar Hoe.—A hoe having a socket-[illegible]

Hog Chain.—See "Chain."

Hog Chain Truss.—See "Truss."

Hoist.—A machine for lifting weights or loads [illegible] of block and tackle or by machinery of any [illegible]

Air Hoist.—A hoisting device, usually consisting [illegible] operated by compressed air.

Assembling Hoist.—A hoist for lifting and assembling [illegible] spans, etc., in the shop or yard of a bridge plant [illegible]

Builders Hoist.—A hoisting apparatus in which the [illegible] are mounted on the same bed.

Cable Hoist.—A hoist in which cables winding [illegible] lift the load.

Chain Hoist.—A hoist in which chains are used for [illegible]

Electrical Hoist.—A hoist operated by an electric [illegible]

Hydraulic Hoist.—A hoist operated by hydraulic power [illegible]

Lever Hoist.—A form of lifting jack employing a lever.

Outrigger Hoist.—A hoist supported by an outrigger.

Pneumatic Hoist.—Same as "Air Hoist," *q.v.*

Sand Hoist.—An apparatus for lifting sand.

Steam Hoist.—A hoist operated by steam.

Hoist Bridge.—Same as "Lift Bridge." See "Bridge."

Hoisting Block.—See "Block."

Hoisting Cable Rope.—See "Rope."

Hoisting Crab.—See "Crab."

Hoisting Engine.—See "Engine."

Hoisting Jack.—See "Jack."

Hoisting Machine.—Any machine used for hoisting [illegible]

Hoisting Shear or **Shears.**—See "Shear."

-up.—A dolly bar for backing up rivets. Called, also, "[illegible]"

g-on Bar.—See "Bar."

ng-up Hammer.—See "Hammer."

w Pile.—See "Pile."

ogeneous.—Having parts of only one kind. Composed of similar parts or [illegible] elements.

ogeneous Steel.—See "Steel."

y-comb.—A condition of having cells like those of a honey-comb, occurring at times in concrete, castings, etc.

—A piece of metal curved or bent so as to catch or grab something. To take hold with a hook.

le Hook.—A large hook suspended from the chain of a crane, used in handling unwieldy boxes and materials.

t Hook.—A brass or iron hook and a spike fixed to a staff or pole, used for pushing or pulling a boat or barge. At times called a "Gaff-setter," "Setting Pole," "[illegible] Hook," and a "Hitcher."

t Hook.—A wooden bar or lever with an iron hook hinged at the end, used for turning over heavy timbers.

ain Hook.—A hook which grips a link of a chain, and serves as a cable stopper.

g Hook.—A strong hook or a wrench used fos separating iron boring rods. Also a bar of iron with a bent prong used in handling logs or timber.

e-bar Hook.—See "Dog."

Beam Hook.—See "Dog."

der Hooks.—See "Dog."

ab Hook.—A hook formed of four large fish hooks.

d Hook.—A tool for twisting iron or steel bars.

Hook.—Same as "Lug Bolt." See "Bolt."

er Hook.—A pair of hooks on the same axis facing each other and fitting closely together when in use.

ble Hook.—A hook on a pulley-block opposite the becket.

ber Hook.—See "Dog."

Block.—See "Block."

Bolt.—See "Bolt."

Chain.—See "Chain."

e's Joints.—See "Joint."

e's Law.—This law states that the deformation of an elastic body is proportional to the force applied, or that the intensity of stress is proportional to the rate of strain.

$$\frac{dp}{dl} = E$$

where

dp = the differential intensity of stress.
dl = the differential of the rate of strain
E = a constant.

-eye.—The eye or loop of a hook.

—Reinforcing bars, bent into a circular shape like hoops, which surround the longitudinal reinforcement of compression members.

—A trough, usually shaped like an inverted frustum of a cone or pyramid, through which materials pass.

Barge.—A boat having a compartment with a movable bottom to receive sand or gravel from a dredging machine and to discharge it by gravity.

Bracing.—See "Bracing."

Clearance.—See "Clearance."

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Horizontal Strut.—See "Strut."

Horizontal Sway Bracing.—See "Bracing."

Horizontal Thrust.—See "Thrust."

Horizontal Truss.—See "Truss."

Horn.—The big end or point of the [illegible] anvil.

Horns.—The stationary arms on a [illegible]

Horse.—A wooden bar with legs for [illegible]

Horse Dolly.—See "Dolly."

Horse Gin.—See "Gin."

Horse Pile Driver.—See "Pile Driver."

Horsepower.—A practical unit of power [illegible] pounds one foot high in one second.

Actual Horsepower or Brake Horsepower.—[illegible] as measured at the flywheel by a friction [illegible]

Calculated Horsepower or Commercial [illegible] the area of the piston.

Dynamic Horsepower.—Same as "Indicated [illegible]

Effective Horsepower.—Same as "Brake Horse[illegible]

Electrical Horsepower.—The power in an [illegible] kilowatts and reduced to horsepower by [illegible]

Indicated Horsepower.—The power developed [illegible] as determined from an indicator diagram. [illegible] in pounds per square inch, multiplied by the [illegible] the piston speed in feet per minute, and divided [illegible]

Nominal Horsepower.—Same as "Commercial [illegible]

Real or True Horsepower.—Same as "Indicated [illegible]

Horseshoe Riveter.—See "Riveter."

Hose.—A flexible tube or pipe for conveying a liquid [illegible] for use.

Air Hose.—A hose for conveying air.

Canvas Hose.—A hose in which the covering is [illegible]

Jet Hose.—A strong hose used for jetting purposes[illegible]

Rubber Hose.—A hose in which the covering is [illegible] and fabric.

Steam Hose.—A hose conveying steam.

Suction Hose.—A reinforced rubber hose running [illegible]

Water Hose.—A hose conveying water.

Hot-box.—A heated journal box of an engine, a [illegible]

Hot Chisel.—See "Chisel."

Hot Cutter.—See "Cutter."

Hot-pressed Paper.—See "Paper."

Hot Saw.—See "Saw."

Hot Short.—A condition of brittleness in iron or steel [illegible]

Hot-short Iron.—See "Iron."

Housing.—In carpentry, the space left in one piece [illegible] of another in order to connect them. The [illegible] a planer. A covering or roofing. A covering [illegible] framing which holds the journal box in place.

Housing Iron.—An iron tool used for placing a strand of oakum in a crack.

Housing Joint.—See "Joint."

Housing Maul.—See "Maul."

Howe Truss.—See "Truss."

Hub.—Any rough protuberance or projection. A block of wood for stopping carriage wheels. The central part of a wheel through which the axle passes, and from which the spokes radiate. A surveyor's stake with a tack in the top to denote line and position.

Reference Hub.—A stake driven flush or nearly so with the ground and used to reference, or to tie, a surveyor's line or point.

Triangulation Hub.—A hub used at the corner of a triangulation system.

Hub Guard.—See "Guard."

Hub Plank.—See "Plank."

Hue.—The predominating spectral color in a color mixture.

Humped-up.—Raised in the centre, synonymous with the term "camel-back."

Hurst.—The ring of the helve of a trip-hammer which supports the trunnions. A sand bank near a river, also a shallow in a river.

Hutton's Formula.—An empirical formula for determining wind-pressure on surfaces inclined to the direction of the wind.

$$P_n = P\,(\sin\alpha)^{(1.84\cos\alpha - 1)}$$

where P_n = the normal component of wind-pressure,

P = the pressure per square foot on a plane perpendicular to the direction of the wind,

and, α = angle of inclination of the surface with the direction of the wind.

Hydrant.—An apparatus for drawing or discharging water directly from a main or pipe.

Hydrated Lime.—See "Lime."

Hydration.—The process of combining or impregnating with water, or the resulting condition.

Hydraulic Activity.—Same as "Activity of Cement." See "Cement."

Hydraulic Buffer.—See "Buffer."

Hydraulic Cement.—See "Cement."

Hydraulic Condenser.—See "Condenser."

Hydraulic Crane.—See "Crane."

Hydraulic Elevator.—See "Elevator."

Hydraulic Energy.—See "Energy."

Hydraulic Gauge.—Same as "Hydraulic Indicator." See "Indicator."

Hydraulic Hoist.—See "Hoist."

Hydraulic Jack.—See "Jack."

Hydraulic Index.—The ratio of the sum of the weight of silica and alumina to the weight of lime in any cement or cement material.

Hydraulic Indicator.—See "Indicator."

Hydraulic Lime.—See "Lime."

Hydraulic Mortar.—See "Mortar."

Hydraulic Press.—See "Press."

Hydraulic Quickness.—Same as "Hydraulic Activity," *q.v.*

Hydraulic-radius.—The ratio of the area of a cross-section of a stream to the length of the wetted perimeter.

Hydraulic Ram.—See "Ram."

Hydraulic Riveter.—See "Riveter."

Hydraulic Strength.—See "Strength."

Hydraulic Valve.—See "Valve."

I-Beam.—See "Beam."

I-Beam Bridge.—See "Bridge."

I-Beam Dogs.—See "Dogs."

I-Beam Girders.—See "Girder

Ice Apron.—See "Apron."

Ice-break, or Ice-breaker.—A

of piles) for the protection of b

Ice Guard.—See "Guard."

Idle Gear.—See "Gear."

Idle Pulley.—Same as "Loose Pulley."

Idler, or Idle Wheel.—See "Wheel."

Ignition.—Firing; setting on fire;

Impact.—The act of striking.

another either moving or at rest.

Coefficient of Impact.—In bridge engineering,

applied load to that of the same load

it is the factor nearly always less

be multiplied in order to find the increment of

load in a manner other than statically.

Impact-Allowance Load.—A percentage

uniform live load. See "Coefficient of Impact."

Impact Load.—See "Load."

Impact-load Stress, or Impact Stress.—Same as "

Impervious.—Not susceptible of being passed through

to the percolation of water.

Impost.—The point where an arch rests on a wall or

from which an arch springs.

Impulse.—The effect of a blow or thrust.

Impulsive Force.—See "Force."

Inch-pound.—A unit of energy or work. The work

through an inch. A unit of moment equal to a

lever-arm of one inch.

Inch-Stress.—See "Stress."

Inch-Ton.—See "Ton."

Incise.—To cut into; to engrave. To form by cutting.

Inclined End Post.—Same as "Batter Post." See "Post

Inclined Plane.—A plane which makes an angle less

horizontal.

Inclined Strut.—See "Strut."

Incrustation.—The act of covering or lining with any

itself.

Indentation Roller.—See "Roller."

Indented.—Notched by a small hollow or depression

Indented Finish.—See "Finish."

Indeterminate Stress.—See "Stress."

Indicated Horsepower.—See "Horsepower."

Indicator.—A marker. The pointer on a steam gauge or any recording instrument. An instrument for measuring the steam pressure, at various positions of the piston, in an engine cylinder.

Deflection Indicator.—Same as "Deflectometer," *q.v.*

Hydraulic Indicator.—A gauge for indicating the pressure of water.

Indicator Diagram.—See "Diagram."

Indirect Stress.—See "Stress."

Indirect Wind-load.—See "Load."

Indirect Wind-stress.—See "Stress."

Induced Stress.—See "Stress."

Indurated Fibre.—See "Fibre."

Inelastic.—Not elastic; rigid; unyielding.

Inertia.—That property of matter by virtue of which it persists in a state of rest or of uniform motion in a straight line unless some force changes that state. The state or quality of being inert. Indisposition to move or to act. Inertness.

Centre of Inertia.—That point in a body which is so situated that the force or combination of forces requisite for producing motion in the said body, or bringing it to rest or changing its motion in any way, is equivalent to a single force applied at the said point. This point coincides with the center of gravity of the body.

Moment of Inertia.—A function of some property of a body or figure—such as weight, mass, volume, area, length, or position—equal to the summation of the products of the elementary portions of such property, of said body or figure, by the squares of their distances from a given axis.

Polar Moment of Inertia.—The moment of inertia about an axis perpendicular to the plane of rotation or to the plane of the area considered.

Inflection.—A change of curvature from concavity to convexity, or *vice versa.*

Inflection Point.—The point where reversal of curvature occurs. Same as point of contraflexure. See "Contraflexure."

Influence Line.—See "Line."

Ingot.—A large mass of metal cast in a mould.

Bled Ingot.—Ingots from the center of which molten steel has escaped, leaving a cavity.

Ingot Iron.—See "Iron."

Ingot Mould.—See "Mould."

Ingot Steel.—See "Steel."

Ingredient.—A component part or element of a compound or mixture.

Initial Set.—See "Set."

Initial Stress.—See "Stress."

Initial Tension.—See "Tension."

Injecting Condenser.—See "Condenser."

Injector.—An apparatus for forcing water into a steam boiler by means of an enclosed jet or nozzle, through which the steam issues at a high velocity, drawing water through a suction pipe and carrying it along to the boiler in a feed pipe, where, because of its high velocity and force of impact, it is able to overcome the back pressure and enter the boiler.

Inlay.—That which is inserted or laid in something else. To do such insertion. To decorate by insertion.

Inner Guard-rail.—See "Guard-rail."

Inner Hip.—See "Hip."

Inner Lock Tender.—Same as "Inside Lock Tender." See "Tender."

Inside Calipers.—See "Calipers."

Inside Lock-tender.—See "Tender."

[illegible]

[illegible]

[illegible]

[illegible]

[illegible].—One whose [illegible]
of work of any kind, and
according to the plans and

Instrument Line.—See "Line."

Instrument-man.—In engineering work,

Insulation.—That state in which the
to other bodies is prevented by the
conductor itself.

Insulator.—A device, fixture, or material

Intake.—The construction work at the
admission of water to said pipe or

Intensity of Stress.—See "Stress."

Interlaced.—Interwoven; intercrossed.

Interlocking.—The action of linking into
mutual or reciprocal action.

Interlocking Device.—Any mechanism for

Interlocking System.—A system of railroad
mechanism insures the setting of a signal
vents the movement of more than one

Intermediate Bent.—Any bent between the

Intermediate Deck.—See "Deck."

Intermediate Girder.—Any girder between the

Intermediate Post.—See "Post."

Intermediate Sill.—See "Sill."

Intermediate Span.—See "Span."

Intermediate Stiffener.—See "Stiffeners."

Intermediate Strut.—See "Strut."

Intermediate Truss.—See "Truss."

Internal Combustion Engines.—See "Engine."

Internal Force.—Same as "Stress," *q.v.*

Internal Stress.—See "Stress."

Intersection.—A place of crossing; cancellation. A
line and a surface.

Double Intersection.—Same as "Double Cancellation."

Multiple Intersection.—Same as "Multiple Cancellation."

Single Intersection.—Same as "Single Cancellation."

Triple Intersection.—Same as "Triple Cancellation."

In the Clear.—Out of the way of moving objects.

Intrados.—The concave curve of an arch. The lower
in position) of a masonry arch.

Semi-intrados.—That portion of the inner arch
arch and its springing line.

Invert.—To turn upside down; to turn end for end.
a sewer or tunnel.

Inverted Arch.—See "Arch."

Inverted Catenary.—See "Catenary."

Inverted Catenary Curve.—See "Curve."

Invoice.—A bill from the seller for goods shipped to the
cerning the size, character, weight, etc., of the
detail. This bill may or may not have the prices

Invoice.—An invoice of goods shipped.

—A curve described by the end of a string as it unwinds from a cylinder while aining taut.

Teeth.—See "Tooth."

—A common but important and abundant metal having a specific gravity of about ght. The pure metal has a white, lustrous appearance, does not harden appreciably n quenching, and is strongly attracted by a magnet, although it cannot be made gnetic except when containing carbon, or while an electric current is passed round it. The term is often applied to a tool or utensil made of iron. Also applied various structural shapes.

e Iron.—See "Angle."

Iron.—An iron ore containing clay.

Iron.—Iron made up in the shape of bars.

-short Iron.—Wrought iron that has been injured and rendered brittle by being worked at a blue heat.

Iron.—An iron extracted from ore occurring in marshy ground.

Iron.—See "Boom."

king Iron.—See "Calking."

Iron.—Iron as it comes from the smelter containing usually from two and a half four per cent of carbon.

nnel Iron.—Same as "Rolled Channel." See "Channel."

rcoal Iron.—Iron made in a furnace where charcoal is used as a fuel.

led Iron.—Iron that is surface-hardened by sudden cooling at the time of casting.

mp Iron.—Same as "Clamp," *q.v.*

d-short Iron.—Iron that is weak and brittle when cold, due to the presence of phosphorus.

mon Iron.—The poorest quality of commercial iron.

rugated Iron.—Sheet iron formed with ridges by passing it between fluted rollers.

ystalline Iron.—An iron which when broken shows a crystalline fracture.

rick Irons.—See "Derrick."

g Iron.—See "Dog."

ble Refined Iron.—Iron made by a process of cutting up bars of refined iron, placing the pieces in piles, then reheating and rerolling into shape.

ous Iron.—An iron having a fibrous texture.

e Iron.—An inferior grade of iron used for puddling.

ing Iron.—See "Forming."

y Iron.—An iron used in foundry work.

vanized Iron.—Iron coated with zinc.

der Iron.—An old term for a structural shape in the form of a girder or I-beam.

Iron.—An iron containing a large amount of silicon.

Iron.—Same as "Grab," *q.v.*

ling Iron.—See "Grappling Iron."

Iron.—A pig iron in which the carbon takes the form of graphite, giving the cture a dark color.

hort Iron.—Iron that is brittle above a temperature denoted by a medium ange color—due to sulphur.

ing Iron.—See "Housing Iron."

Iron.—Soft steel cast in ingots, sometimes with about three per cent of copper

—Same as "Scrap Iron," *q.v.*

—See "Knee Iron."

—See "Making Iron."

[illegible]

[illegible] **Iron.**—The lowest [illegible] specimens.

Norway Iron.—A very pure wrought [illegible] hooks for blocks, etc.

Pig Iron.—A term applied to cast [illegible] moulds, giving small-size bars [illegible]

[illegible] Iron.—See "[illegible]"

Red-short Iron.—Iron containing [illegible] crack when bent at a red heat, but [illegible]

Refined Iron.—An iron made from [illegible] and rolled.

Rolled Iron.—An iron that has passed [illegible]

Sampling Iron.—See "Sampling Iron." [illegible]

Scrap Iron.—Old iron no longer suitable [illegible] iron.

Screed-iron or Scrid-iron.—See "Screed-iron [illegible]

Sheet Iron.—Iron which has been rolled [illegible]

Soldering-iron.—See "Soldering-iron."

Swedish Iron.—A very pure wrought iron [illegible]

T or Tee Iron.—Iron rolled into the shape of [illegible] the letter T.

Toggle Iron.—A connecting detail for a toggle.

Weak Iron.—White, brittle pig-iron.

Weld Iron.—A term suggested for wrought iron, [illegible]

Wire Iron.—A ductile iron from which wires are [illegible]

Wrought Iron.—In its perfect condition, wrought [illegible] to impurities (to a certain degree) being [illegible] condition.

Z-Bar Iron.—Iron rolled in the shape of a bar [illegible] letter Z, but with the web at right angles to the [illegible]

Iron-bound.—Bound together by bands of iron.

Iron-founder.—One who makes iron castings.

Iron Foundry.—See "Foundry."

Iron Furnace.—See "Furnace."

Iron-gray.—A gray hue.

Iron-master.—A manufacturer of iron.

Iron-oxide.—An intimate combination of oxygen and [illegible] "Ochre."

Iron-red.—A red of somewhat orange tint as produced [illegible]

Iron Rust.—See "Rust."

Iron Sand.—See "Sand."

Iron Saw.—See "Saw."

Iron Scab.—See "Scab."

Iron Scale.—See "Scale."

Iron-smith.—A worker in iron.

Iron-stain.—A stain made by iron rust on some object.

Iron Stone.—See "Stone."

Ironwork.—See "Work."

Iron-worker.—A bridgeman or man who helps erect iron or steel.

Iron-works.—The plant or place where iron structures are fabricated and assembled.

Irregular Course.—See "Course."

Irregular Fracture.—See "Fracture."

Isodomon.—One of the varieties of masonry in Greek architecture in which the blocks forming the courses were of equal thickness and of equal length, and so disposed that the vertical joints of the upper course came over the middle of the blocks in the course immediately below, all blocks being joined by horizontal dowels.

Isometric Projection.—See "Projection."

Isosceles.—Having two legs or sides equal, as in a triangle.

Isotropic.—Having the same physical properties in every direction.

J

Jack.—A lifting apparatus. A mechanical device, appliance, or part of a machine. To pry up or lift with a jack.

Ball-bearing Jack.—A jack having ball bearings to take up the thrust from the load and reduce the friction of operation.

Beveled-gear Jack.—A jack operated by power applied through bevel gears.

Camber Jack.—Any special jack used for putting the initial camber in a truss in place of wooden wedges.

Differential Jack.—Any jack worked by differential gears.

Differential Screw-jack.—A screw-jack having a differential screw.

Hoisting Jack.—A lifting device in which a screw-jack is employed.

Hydraulic Jack.—A device for lifting heavy weights or exerting great force by means of liquid pressure from a hand-pump connected with a large-bore cylinder and a piston working therein.

Lazy Jack.—A mechanism consisting of compound levers pivoted together.

Lever Jack.—A jack worked by a lever.

Lifting Jack.—A screw jack worked by a worm wheel to which a handle is attached.

Rack-and-pinion Jack.—A jack using a rack and pinion to attain its lifting motion.

Rail Jack.—Same as "Track Jack," *q.v.*

Railroad Jack.—Same as "Track Jack," *q.v.*

Ratchet Jack.—Any jack worked with a ratchet.

Screw Jack.—A large screw working in a nut set in a strong frame or forming a part thereof, which in turn serves as a base to carry the load.

Steamboat Jack.—A ratchet jack similar to and operating on the same principle as a steamboat ratchet, but with bearing shoes at the ends of the screws so that a pressure may be exerted between two objects or parts of a structure.

Timber Jack.—An apparatus for lifting timber.

Track Jack.—A lever jack having a tongue near the bottom of the stem and on the side opposite the lever. This tongue can readily be inserted under a rail or tie and a portion of the track raised by pumping the lever.

Truck Jack.—A lifting jack hung from a truck.

Whiskey Jack.—A hydraulic jack in which spirits are used instead of water.

Windlass Jack.—A jack having on the nut which surrounds its screw a crown wheel operated by a pinion and a crank.

Jack Arch.—See "Arch."

Jack-bores.—The bores of a jack either on the inside or the outside.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Jack-head Pump.—See "P

Jack-knife Bridge.—See "

Jack Plane.—See "Plane."

Jack Rafter, or Jack Rib.—See "

Jackroll.—A windlass.

Jack Screw.—Same as "Screw Jack."

Jack Shaft.—See "Shaft."

Jack Stringer.—See "Stringer."

Jack Timber.—A timber in a bay, which, as
piece, is shorter than the rest.

Jag Bolt, or Jag Spike.—Same as "

Jambs.—The sides of an opening through

Jam Nuts.—Same as "Check Nuts." See "

Jaw.—Any part of a construction, which,
resemblance to the jaw of an animal.

Jaw Clutch.—See "Clutch."

Jaw Coupling.—Same as "Claw Coupling." See

Jaw Plate.—See "Plate."

Jemmy.—A short crowbar. Also called "

Jet.—A spouting or spurting, as of water or

Aeration Jet.—A jet of water through which

Pump Jet.—Same as "Jet Pump." See "

Rose Jet.—A jet of water issuing through a
end and five openings around the sides with
degrees to that of the axis of the nozzle.

Steam Jet.—A flow of steam from an orifice.

Water Jet.—A flow of water, at high velocity, from

Jet Chain.—See "Chain."

Jet Condenser.—See "Condenser."

Jet Hose.—See "Hose."

Jet Nozzle.—See "Nozzle."

Jet Pipe.—See "Pipe."

Jet Pump.—See "Pump."

Jetted Pile.—See "Pile."

Jetting.—Putting down by means of a jet.

Jetty.—A structure of wood, stone, or mattress
serving for a wharf or pier, or as a mole, rampart,
charge, or direct a current, and to protect a

Jetty Head.—See "Head."

Jib.—The upper projecting member or arm of a crane

Jib Crane.—See "Crane."

Jig.—Any tool or fixture used to guide cutting tools.

Jigger.—A small, light, or light-running mechanical
a rapid, jerky motion. Any subordinate mechanical
definite name is attached. A warehouse crane.

Jigger Pump.—See "Pump."

Jig Saw.—See "Saw."

Jim-crow.—An implement for bending or straightening

Jimmy.—Same as "Jemmy," *q.v.*

Jimmy-wink.—Any short, light, stationary derrick used

A particular piece of work. Any undertaking.

k.—See "Work."

Pulley.—See "Pulley."

Wheel.—See "Wheel."

—A stub tenon on the end of a post or piece of timber, which prevents it from oving laterally.

Beam.—See "Beam."

piece.—The upright member in the middle of a truss; a king post.

Post.—See "Post."

Truss.—See "Truss."

Wheel.—See "Wheel."

Work.—See "Work."

—The place or part in which two things or portions of one thing are joined or united. The mechanism, method, or means by which such junction is effected.

tting Joint.—A square joint confined to a single plane where the parts meet. In contra-distinction to a lap-joint where the splice is shingled.

gle Joint.—A joint in which two pieces meet at an angle.

-and-socket Joint, or **Ball Joint.**—A joint having a spherical surface, or a ball working in a socket.

d Joint.—Mortar in a masonry joint forming a bead.

d Joint.—A horizontal joint or one perpendicular to the line of pressure on the masonry.

veled Joint.—An angle joint in which the contact surfaces make equal angles, other than a right angle, with the axes of the parts joined.

rd's-mouth Joint.—A joint in timber where an inclined member is dapped over a horizontal member.

ing Joint.—A joint formed by the ends of several component pieces in one ine, no two lines being cut at the same place.

k Joint.—To overlap pieces so that the joints will not occur near together, avoiding thereby excessive weakening of the member.

t Joint.—A joint in which the ends of the pieces are square and press against each other.

mfered Joint.—Same as "Mitre Joint," *q.v.*

ompression Joint.—A joint where compression members meet. A splice in a compression member.

ursing Joint.—A joint between two voussiors in masonry.

amp Joint.—A joint between plates of metal in which the edges are thinned by hammering.

-and-ball Joint.—Same as "Ball-and-socket Joint," *q.v.*

pped Joint.—A joint made between two pieces by cutting away corresponding portions of each so that they fit together with surfaces flush with each other.

uble-step Joint.—A dapped joint in which the projecting timber has two steps.

wel Joint.—A joint that is strengthened by a pin or a dowel.

ow Joint.—A joint where two pieces of pipe meet at an angle. A form of pipe-fitting for joining two such pipes.

Joint.—A joint in which movement for expansion and contraction is allowed.

Joint.—A joint in which the adjacent faces have been planed. Also a voussoir joint that shows on the face of an arch.

Joint.—Same as "Dove-tail Joint," *q.v.*

—Any joint held fast by means of the addition of one or more bolts.

—The socket of a spigot and faucet joint.

—A joint between two rails connected by fishplates bolted thereto.

[illegible] on their faces.

[illegible] **Joint.**—A joint between [illegible]

[illegible] in the same [illegible]

[illegible] **Joint.**—A butt joint in [illegible]

Hinged Joint.—A joint in which [illegible]
permitting a rotating motion [illegible]

Hip-joint.—The junction of the top [illegible]

Hooke's Joint.—A contrivance by [illegible]
one shaft to another not lying in the same [illegible]

Housing Joint.—In carpentry, a joint [illegible]
portion of one piece to allow the [illegible]

Jump Joint.—Same as "Butt Joint," *q.v.*

Knuckle Joint.—A flexible joint formed by [illegible]

Lap Joint.—A joint in which the plates [illegible]

Lead Joint.—A joint in a pipe, filled with [illegible]

Lock Joint.—A joint made by the locking [illegible]
around a pile by inserting wooden keys [illegible]

Loose Joints.—A joint in which the parts are [illegible]

Masonry Joint.—A joint between masonry [illegible]

Match Joint.—Same as "Tongue-and-groove [illegible]

Miter Joint.—A special case of a beveled joint [illegible]
angles of forty-five degrees with the axes of the [illegible]

Mortised Joint.—The joint formed between two pieces [illegible]
in it to receive the tenon of the other piece.

Open Joint.—A joint in which the parts are slightly [illegible]

Overlapping Joint.—Same as "Lap Joint," *q.v.*

Pillow Joint.—Same as "Ball-and-socket Joint," *q.v.*

Pin Joint.—Any joint in which the parts are held [illegible]

Pipe Joint.—The joint between two pieces of pipe.

Planed Joint.—A joint in which the contact surfaces [illegible]
surfaces finished in a machine.

Putty Joint.—A pipe joint made tight with putty.

Rabbet Joint.—Same as "Half-and-half Joint," *q.v.*

Rail Joint.—The joint between railway rails.

Ring Joint.—A circular flange joint.

Riveted Joint.—A joint in which the parts are held [illegible]
and rivets.

Rule Joint.—A pivoted joint similar to a hinged joint, [illegible]

Rust Joint.—A joint between pieces of metal made by [illegible]
missible in good bridge engineering practice.

Saddle Joint.—A sheet metal joint in which one [illegible]
upturned edge of the next.

Scarf Joint.—A joint between two pieces made by [illegible]
so that when the parts are placed together they [illegible]

[illegible]

Joint.—A joint in which one [illegible] a common sleeve or coupling like the ordinary pipe joint.

ckle Joint.—A joint formed by a clevis or a shackle with a bolt.

ove Joint.—A joint in brick-work obtained by shoving the brick [illegible] so as to pile up mortar at its end and thereby fill the vertical joint.

eve Joint.—An expansion joint in conduits, pipe lines, etc., in which the parts it into a common sleeve.

Joint.—Same as an "Expansion Joint."

lder Joint.—A joint made by soldering two pieces together.

lice Joint.—A joint formed by using scabs or splice bars or plates to make the connection between the two parts.

uare Joint.—A timber joint in which the ends are brought squarely together.

ap Joint.—Same as "Strap Hinge," *q.v.*

ump Joint.—A joint having a stump to prevent folding except in one direction, as in a folding rule.

rface Joint.—A connection between metal plates by joining the edges with flanges or laps riveted or soldered to the parts.

wivel Joint.—A joint utilizing a swivel to permit twisting of the parts with respect to each other.

ypher Joint.—Same as a "Chamfered Joint," *q.v.*

ension Joint.—A splice in tension.

himble Joint.—An expansion sleeve-joint in a pipe line.

oggle Joint.—A union of two parts by means of a toggle.

ongue-and-groove Joint, or **Tongue Joint.**—A joint made by one part having a projecting tongue fitting into a corresponding groove in the other part.

russ Joint.—Any joint in a truss.

uck Joint.—A joint in masonry presenting the appearance of tusks.

wist Joint.—An ordinary wire splice made by twisting.

nion Joint.—A pipe coupling. Also called a "Pipe Union." See "Union."

niversal Joint.—An arrangement by which one part may be made to move freely in all directions while rotating with another part.

Water Joint.—A joint between parts precluding the passage of water.

Weather Joint.—A masonry joint where the mortar forms an outward sloping surface from the bottom of the upper course to the top of the lower course.

Welded Joint.—The union of metallic pieces by welding.

Wire Joint.—A joint between two wires made by twisting their ends together.

t Bolt.—See "Bolt."

t Coupling.—See "Coupling."

t-end.—The iron end-piece about which another part moves as on a pivot.

nter.—A tool for filling the cracks between courses of stone in masonry. A long planer to straighten the edges of boards. A tool for heading a joint.

t File.—See "File."

t Hinge.—See "Hinge."

of Rupture.—See "Rupture."

Pipe.—See "Pipe."

Splice.—See "Splice."

t.—To fit or furnish with joists. One of the horizontal pieces usually laid in equidistant rows to which flooring is nailed.

nding Joists.—Joists used as girders to sustain common joists.

idging Joists.—Common joists.

eel Joists.—Joists made of steel.

mber Joists.—Joists made of timber.

ack Joists.—A joist or a stringer which is placed under a track.

[illegible]

[illegible] Packing.—See "Packing."

Jumbo.—A term descriptive of anything [illegible]

cinder notch of a blast furnace [illegible]

Jump.—An abrupt rise in a level [illegible]

Jumper.—A dolly; a monkey. A [illegible]

Jumper Drill.—See "Drill."

Jumping.—Upsetting a bar, etc., or [illegible]

it on end.

Jump Joint.—See "Joint."

Jump-up.—See "Jumping."

Jump Weld.—See "Weld."

Junction Shaft.—See "Shaft."

Junk.—Worn out and discarded material, [illegible]

may be turned to some use; such as [illegible]

again sold. Same as "Scrap," *q.v.*

Junk-dealer.—One who buys junk.

Junk Iron.—Same as "Scrap Iron." See [illegible]

Jut.—To project out. To shove or butt. [illegible]

Jute.—The fibre of a plant grown in India, [illegible]

Jute Packing.—See "Packing."

Jutty.—A pier, mole, or jetty.

K

Kahn Bars.—See "Bar."

Keckle.—To cover or guard by winding with [illegible]

Kedge.—A small anchor with an iron stock. To [illegible]

Keel.—The principal timber in a boat, vessel, etc., [illegible]

along the bottom and supporting the whole [illegible]

Keepers.—The pieces of metal or wood which [illegible]

its motion.

Keg.—A cask-shaped vessel of indefinite size, but [illegible]

usually from five to ten gallons.

Kellogg Truss.—See "Truss."

Kerf.—The space, opening, or narrow slit made in [illegible]

Kettle.—A vessel of iron, copper, or other metal, [illegible]

for heating tar, asphalt, etc.

Key.—Anything that operates a locking mechanism, [illegible]

of parts on each other; such as the central stone [illegible]

inserted in a longitudinal slot in a shaft to prevent [illegible]

a piece inserted in the back of a board to keep it [illegible]

controlling a valve, moving a nut, etc.

Adjusting Key.—A wrench in which the jaws are [illegible]

Cotter Key.—Same as "Cotter," *q.v.*

Key Bed.—See "Bed."

Key Bolt.—Same as "Cotter Pin." See "Pin."

Key Pile.—See "Pile."

Keystone.—See "Stone."

ne Column.—See "Column."

way.—A slot cut in a shaft or hub of a gear or pulley to receive the key.

Wrench.—See "Wrench."

le.—The bucket used for raising earth, stone, etc., from shafts or mines.

—To hold molten steel in a laddle, furnace, or crucible until the ebullition of gas ceases and the metal becomes quiet.

g.—The act of holding steel to kill it. See "Kill."

—A shaft furnace for roasting ore, limestone, etc., where a very high temperature is required.

ement Kiln.—A rotating furnace having a slight slope, receiving the pulverized, raw material at its upper end and gradually working it toward the lower end where the fire is located.

me Kiln.—A furnace in which limestone is calcinated.

mber Kiln.—An enclosed chamber artificially warmed, in which sawn lumber is placed to be heated so as to free it from moisture and prevent warping.

-drying.—An artificial method of seasoning timber, in which it is put into a kiln and exposed to a current of hot air.

watt.—An electrical unit of power equal to one thousand watts, or 1.3405 horse-power.

watt-hour.—The customary unit of electric energy, used in the sale of electricity, equal to one thousand watt-hours.

matics.—That branch of the science of mechanics which treats of the motion of bodies without reference to the cause or force producing it.

tic.—Pertaining to or producing motion.

tic Energy.—See "Energy."

tics.—That branch of the science of mechanics which treats of forces causing motion or changing motion in bodies.

Post.—See "Post."

-post Truss, or **King Truss.**—See "Truss."

Rod.—See "Rod."

—A knot-like contraction. A twist or a sharp sudden bend in a piece. To twist or contract into knots.

—A sharp-pointed hill; a jutting point. A stress unit equal to one thousand pounds.

h.—The graphite forced out from molten pig iron during its solidification.

—A kind of cement; lute and putty. A box, chest, or canvas bag for holding tools. To pack in a kit.

veting Kit.—A kit of tools for driving field rivets.

ded Rubber.—See "Rubber."

, or Knee Brace.—A short diagonal brace, used to connect a batter brace or a vertical post in a span to an over-head strut.

-braced Trestle.—See "Trestle."

-iron.—An L-shaped angle-iron used to strengthen a joint formed by two timbers in a frame.

der.—A pad used on the knee by bridgemen, carpenters, etc., for protecting the nee while at work.

movement.—The movement in a joint like that of a knee.

-edge.—A sharp edge similar to that of a knife blade. However, it is often applied to rather blunt edges.

ing-bucker.—A tool made from a strong, flat bar of iron, used for breaking or bucking ore or stone.

Stone.—See "Stone."

—The hard mass of wood formed in the trunk of a tree at a branch, with the grain distinct and separate from the grain of the trunk. A knob in an arch. An intertwining of the parts of one or more ropes, cords, or strips for the purpose of fastening them together. The act of tying a knot.

[illegible]

[illegible] Knot.—A [illegible]

[illegible] Knot.—See [illegible]

[illegible] Knot.—Same as a "[illegible]

Half Hitch Knot.—See "Ketchum's [illegible]

Large Knot.—A sound knot in timber [illegible]

Loose Knot.—A knot in timber, not [illegible]

Overhang Knot.—Same as "Simple [illegible]

Pin Knot.—A sound knot in timber [illegible]

Pith Knot.—A sound knot in timber [illegible] inch in diameter.

Reef Knot.—Same as a "Square Knot," [illegible]

Rolling Hitch Knot.—See "Ketchum's [illegible]

Rotten Knot.—A knot in timber softer than [illegible]

Round Knot.—A knot in timber which is [illegible]

Round Turn and a Half Hitch.—See "[illegible]

Running Knot.—Any knot made in such a [illegible] the rope is being pulled.

Sheep Shank Knot.—A form of knot made in a [illegible]

Sheet Bend.—See "Ketchum's Hand Book," [illegible]

Sheet Bend Knot with a Toggle.—See "[illegible]

Simple Knot.—See "Ketchum's Hand Book," [illegible]

Slip Knot.—See "Ketchum's Hand Book," [illegible]

Sound Knot.—A knot in timber, which is solid [illegible] wood surrounding it.

Spike Knot.—A knot in timber which knot is sawn [illegible]

Square Knot.—See "Ketchum's Hand Book," [illegible]

Standard Knot.—A sound knot in timber not over [illegible]

Stevedores' Knot.—See "Ketchum's Hand Book," [illegible]

Timber Hitch and Half Hitch Knot.—See "[illegible] 445.

Timber Hitch Knot.—See "Ketchum's Hand Book," [illegible]

Wall Knot.—See "Ketchum's Hand Book," pages [illegible]

Wall Knot Crown.—See "Ketchum's Hand Book," [illegible]

Knot Maul.—See "Maul."

Knotty.—Having many knots. Said of timber.

Knuckle Gearing.—See "Gearing."

Knuckle Joint.—See "Joint."

K Type Truss.—See "Truss."

Kutter's Formula.—A formula for evaluating the [illegible] formula for the mean velocity of the current in [illegible]

$$v = C\sqrt{rs}$$

where v = velocity in feet per second,

C = a coefficient,

$$= \frac{41.6 + \frac{1.811}{n} + \frac{0.00281}{s}}{1 + \left(41.6 + \frac{0.00281}{s}\right)\frac{n}{\sqrt{r}}}$$

r = hydraulic radius,

s = sine of slope,

and n = coefficient of roughness.

Kyanizing.—A process for preventing the decay of wood by impregnating it with chloride of mercury, patented by J. H. Kyan, in 1832.

L

Laced Strut.—See "Strut."

Lacing.—A system of bars not intersecting each other at the middle, used to connect two leaves of a strut in order to make them act as one member.

Angle Lacing.—A system of lacing in which angle-irons are used in place of bars.

Double Lacing.—Erroneously used for "Latticing," *q.v.*

Double Riveted Lacing.—Lacing in which each bar is connected by two rivets at each end.

Single Lacing.—Same as "Lacing," *q.v.*

Lacing Bar.—See "Bar."

Ladder Bracing.—See "Bracing."

Ladder Dredge.—See "Dredge."

Ladder-way.—A space or opening for ascending or descending by a ladder.

Ladder Work.—See "Work."

Ladle.—A large vessel or pot for holding, transporting, and pouring molten metal.

Ladle-barrow.—A special wheel-barrow for carrying a ladle of molten metal.

Lag.—The amount of retardation of some movement, as the lag of the valve in a steam engine. To hang back. The outside covering of a steam boiler to prevent radiation. The vertical timbers nailed to a "Lag Pile," *q.v.* To fasten down with "Lag Screws," *q.v.*

Lag-bellied.—Any construction having a slack, drooping belly.

Lag Bolt.—Erroneously used for "Lag Screw," *q.v.*

Lagged Pile.—See "Pile."

Lagging.—Same as "Sheeting," *q.v.* Also planking or timbers fastened by lag screws.

Lag Screws.—See "Screw."

Laid-up.—A term used in riveting to denote that the dolly bar is tight against the head of the rivet preparatory to driving.

Laitance.—Same as "Laitance of Cement." See "Cement."

Laitier Cement.—See "Cement."

Lamellar Structure.—See "Structure."

Laminar.—Composed of thin plates or layers.

Laminated.—Having plates or scales. Scaly.

Laminated Arch.—See "Arch."

Lampblack.—A fine, black pigment consisting of particles of nearly pure carbon, used for making paints, ink, etc.

Lance Wood.—See "Wood."

Lanch.—Same as "Launch," *q.v.*

Land.—The smooth uncut part of the faceplate of a slide-valve in a steam engine. To put on or to bring to shore.

[illegible]

[illegible] the ground. A [illegible]

[illegible] nearly similar manner.

Langlay Rope.—Wire rope in which [illegible] as the strands are twisted.

Lantern Pinion.—See "Pinion."

Lantern Wheel.—See "Wheel."

Lanyard.—A cord or line used for [illegible] rope attached to a bucket for taking

Lap.—To place one piece upon another,

Lap Joint.—See "Joint."

Lap Riveting.—See "Riveting."

Lap Seam.—See "Seam."

Lap Splice.—See "Splice."

Lap Weld.—See "Weld."

Large Knot.—See "Knot."

Larry.—Same as "Lorry," *q.v.*

Lash.—To secure by tying. To burst or break

Lashing.—A cord, rope, wire, or chain for

Latch.—A device for catching or retaining place with a latch.

Latch-bar.—A bar used for latching.

Latch-catch.—A catch which holds the latch in

Latent Heat.—See "Heat."

Lateral.—At right angles to the line of motion; system.

Bottom Laterals or **Lower Laterals.**—Laterals in the

Top Laterals or **Upper Laterals.**—Laterals in the

Lateral Bracing.—See "Bracing."

Lateral Clearance.—See "Clearance."

Lateral Contraction.—See "Contraction."

Lateral Diagonals.—See "Diagonals."

Lateral Rods.—See "Rod."

Lateral Section.—See "Section."

Lateral Strain.—See "Strain."

Lateral Stress.—See "Stress."

Lateral Struts.—See "Strut."

Lateral System.—A system of tension and compression of a horizontal truss, connecting the opposite chords to transmit wind pressure to the piers or abutments from passing trains or other loads, and to hold the

Lath.—A thin, narrow strip of wood, used in buildings paving blocks in pavements on heavy grades so horses.

Creosoted Lath.—A lath treated with creosote.

Metal Lath.—A perforated metal sheet used for reinforcing

Timber Lath.—A lath made from timber.

Lathe.—A machine tool for turning various materials,

Metal Lathe.—A lathe which is used exclusively for

Timber Lathe.—A lathe used exclusively for turning

Latitude.—In surveying, one of the two coordinates of east and west axis in a system of rectangular coordinates

—Same as "Latticing," *q.v.*

Angle.—See "Angle."

Bar.—See "Bar."

Bridge.—See "Bridge."

Girder.—See "Girder."

e Truss.—See "Truss."

ing.—A system of bars crossing each other at mid-length, used to connect the two leaves of a strut in order to make them act as one member. Generally the crossed bars are riveted together at their intersection.

uble Latticing.—Same as "Latticing," *q.v.*

gle Latticing.—Erroneously used for "Lacing," *q.v.*

ch.—To move heavy bodies by pushing. The sliding of an object, which will float, into the water. A small power boat.

ching Ways.—See "Ways."

ching Wedges.—See "Wedges."

hardt's Formula.—A formula pertaining to the fatigue of metals.

$$m = p_1 + \frac{n}{m}(f - p_1)$$

where m = maximum stress.
p_1 = repetition limit when $n = 0$.
n = minimum stress.
f = ultimate static strength.

This formula does not properly apply to any part of bridge engineering.

er-out.—The person in a bridge shop who lays out the steelwork with templates.

out.—A plan or arrangement of the parts of a structure shown on a drawing.

ternate, or Alternative Layout.—One of two or more different layouts, or schemes, for the same project.

eneral Layout.—A drawing showing an elevation, plan, and cross section for a structure, and any other notes—such as borings.

y Jack.—See "Jack."

y Pinion.—See "Pinion."

d.—The course of a running rope from end to end. In a steam engine, the arrangement of the valves. A passageway. The average distance required to be traveled to remove the earth of an excavation so as to form an embankment, or the average haul.

d.—One of the useful metals remarkable for its softness and durability, having a specific gravity of 11.3. To cover, fasten, smooth, or polish with lead.

acklead.—A name sometimes used for graphite.

Lead.—Lead which has been cast in a mould.

led Lead.—Same as "Sheet Lead," *q.v.*

Lead.—An oxide of lead—used as a pigment for paint.

et Lead.—A thin plate of lead made by passing a flat ingot repeatedly through rollers.

ite Lead.—A mixture of the carbonate and the hydrated oxides of lead. Used as pigment for paint.

Gray.—Colored like lead.

Beam.—See "Beams."

Line.—Same as "Lead Line." See "Line."

Pile.—See "Pile."

Wheels.—See "Wheels."

—See "Joint."

—See "Line."

—See "Pipe."

[illegible]

[illegible] called a leak. To [illegible]

[illegible] method of [illegible]

Principle of Least Work.—The [illegible] such values that the internal energy [illegible]

Leaves.—The cogs of pinions. The portions of [illegible] The two or more main components of [illegible]

Ledge.—A part projecting over like a shelf, [illegible] boards to hold them together.

Ledger.—A bar, beam, or stone that lies flat, [illegible] forming a scaffold. A book for keeping [illegible]

Leeward.—The side opposite to that from [illegible]

Left-handed Nut.—See "Nut."

Left-handed Thread.—See "Thread."

Left-handed Screw.—See "Screw."

Leg.—Anything that resembles the limb of [illegible] in supporting a load; e.g., the inclined [illegible] of an angle-iron separated by the heel. [illegible]

Stiff Leg.—A leg capable of taking compression [illegible]

Leg Bridge.—See "Bridge."

Lemniscate.—A curve resembling a figure eight [illegible] of the point at which the tangent to the [illegible] dicular let fall upon it from the center.

Length.—Extension from end to end. Distance [illegible]

Effective Length.—That length of a member [illegible] designing it. In a girder or truss the distance [illegible]

Gauge Length.—The original length marked on a test [illegible] the elongation.

Panel Length.—The distance between two adjacent [illegible] of a truss.

Unsupported Length.—The length of a compression [illegible] points of lateral restraint.

Lens.—A piece of transparent substance, usually glass, [illegible] having the power of refracting light.

Lenticular Arch.—See "Arch."

Lenticular Truss.—See "Truss."

Letting.—The awarding of a contract to a bidder.

Sub-letting.—The re-awarding of a contract or a portion [illegible] bidder to another party.

Level.—To make horizontal, or to bring into a plane [illegible] to a common level. To work with a leveling instrument [illegible] securing a horizontal line of sight.

Carpenter's Level.—A plummet attached to a wooden [illegible] attachment of the plumb-line perpendicular to the [illegible] "Spirit Level," *q.v.*

[illegible]

...y Level.—An engineer's level having a short telescope [illegible] supporting bar and vertical axis.

...ineer's Level.—A leveling instrument consisting of a telescope [illegible] hairs, mounted on a supporting frame which can be brought to a level [illegible] of screws, and which can be rotated about a vertical axis. A tripod serves to hold the instrument at a convenient height for the observer.

...ying Level.—A hasty, preliminary leveling over a proposed route.

...and Level.—A small leveling instrument held in the hand for approximating differences in elevation.

...cke Level.—A type of hand-level consisting of a small tube with a [illegible] mounted on the upper side and a refracting prism or a reflector to show the bubble in the field of vision.

...ecise Level.—A modification of the Y level with improvements and additions permitting of more accurate work.

...it Level.—A long block of wood or a metal frame of similar size and shape holding a short, slightly curved glass tube closed at the ends and nearly filled with ether. The bubble, thus produced, will come to the center of the tube when the apparatus is level.

Surveyor's Level.—Similar to "Engineer's Level," *q.v.*

Water Level.—The elevation at which water stands.

Y Level.—A leveling instrument having its telescope in Y standards, permitting of a rotation therein and a removal therefrom with a reversal of [illegible] to facilitate the process of adjusting.

...l Book.—A field book in which to record level notes.

...eler.—One who does leveling work. A small stone used illegitimately in masonry to adjust the elevation of a large, cut stone.

...veling Instrument.—A surveyor's or engineer's level, *q.v.*

...veling Pole, or Leveling Rod, or Leveling Staff.—See "Rod."

...l-man.—The man in a survey party who operates the level.

...l-notes.—Records of back-sights, heights of instrument, foresights, and elevations as written by the observer in the level book.

...ver.—A mechanical element, or simple machine, consisting of a bar or rigid piece of any shape which is acted upon by two forces severally tending to rotate it about a fixed axis. Any rod or bar used for prying.

Hand Lever.—A hand tool consisting of a small steel bar for prying. The handle by which an engine or a machine is started.

Laws of the Lever.—An early day expression used to denote the conditions of equilibrium of three forces in one plane. They are as follows:

First.—The three parallel forces applied to one body must balance each other and lie in the same plane.

Second.—The two extreme forces must act in the same direction.

Third.—The middle force must act in the opposite direction.

Fourth.—The magnitude of each force must be proportional to the distance between the other two.

Link Lever.—A controlling lever for moving the link of a valve gear in a steam engine.

...erage.—Lever power, or the arrangement by which lever power is gained.

...er-arm.—The perpendicular distance from the centre of moments to the line of action of a force; or in the case of a couple, the distance between the lines of action of the two equal and parallel forces.

... Draw Bridge.—See "Bridge."

...—See "Hoist."

...—See "Jack."

...—See "Valve."

[illegible]

[illegible]

Lift.—To move or heave [illegible]

[illegible]

Dead Lift.—Same as "Dead [illegible]

Lift Bridge.—See "Bridge."

Lift Hammer.—See "Hammer."

Lifting Bridge.—Same as "Lift [illegible]

Lifting Dock.—See "Dock."

Lifting Jack.—See "Jack."

Lift Pump.—See "Pump."

Lift Span.—See "Span."

Lighter.—A scow, barge, raft, or other [illegible] from the shore.

Lime.—A product made by heating [illegible] in kilns. As it comes from the kilns in a [illegible]

Air Slaked Lime.—Lime which has [illegible]

Caustic Lime.—Same as "Quick Lime," [illegible]

Common Lime.—Same as "Lime," q.v.

Fat Lime.—A lime rich in protoxide of [illegible]

Flour of Lime.—Air-slaked lime reduced to the [illegible]

Free Lime.—In cement, lime that has not [illegible]

Hydrated Lime.—Same as "Slaked Lime," [illegible]

Hydraulic Lime.—A lime made from [illegible] calcination, enters into combination with a [illegible] it the additional property of hardening [illegible]

Magnesian Lime.—A term applied to limes [illegible] magnesia.

Meager Lime.—A lime that is lacking in the [illegible]

Neat Lime.—Lime mixed with water and used [illegible]

Paste Lime or Putty Lime.—A thick mixture of [illegible]

Quick Lime.—The commercial lime, or a calcium [illegible]

Rich Lime.—Same as "Fat Lime," *q.v.*

Silicate of Lime.—A union of silica and lime [illegible]

Slaked Lime.—A lime that has been mixed with [illegible]

White Lime.—A solution or preparation of lime [illegible]

Lime-cement Mortar.—See "Mortar."

Lime Kiln.—See "Kiln."

Lime Mortar.—See "Mortar."

Limestone.—A rock of sedimentary origin [illegible] ($CaCO_3$).

Dolomitic Limestone.—A limestone containing more [illegible] of magnesia.

Magnesian Limestone.—A limestone containing [illegible] of magnesia.

Oölitic Limestone.—A granular limestone in which [illegible] form of a sphere, producing a resemblance in the [illegible] the name.

Lime-wash.—Same as white-wash or white lime, *q.v.* [illegible]

Limit Load.—See "Load."

Limit of Elasticity.—Same as "Elastic Limit," *q.v.*

[illegible]—The precise boundaries between two contiguous regions of magnitude or quantity.

Limnoria.—A small crustacean about the size of a grain of rice requiring both air and water for its existence. It works on the surface of wood with its claws or mandibles taking off at one time a layer about one-half inch thick. It is usually most active in brackish waters at low water level.

[illegible] Pin.—See "Pin."

Line.—A unit of length, as one tenth or one twelfth of an inch. A row of anything. A limit, division, or boundary. A length without breadth, or the trace of a moving point. A string, cord, or slender rope. A mark drawn by a pen or pencil. To cover or fill the inside of anything. To keep things in line. A railway.

Abutment Line.—The closing line of an equilibrium polygon.

Air Line.—The shortest distance between two points on the earth's surface.

Base Line.—A line adopted as a fundamental line in a survey from which other lines are run. Used in triangulation work.

Broken Line.—Any line composed of two or more straight lines.

Carpenter's Line.—Any light cord or string stretched between nails, used by carpenters to line up work.

Centre Line.—A line connecting the centre points of anything.

Chalk Line.—A cord rubbed with chalk, used for marking lines on surfaces by being held taut and snapped with the fingers. Also the mark left by such a process.

Clearance Line.—A line on a diagram showing the minimum clearance allowed.

Closing Line.—The last line or side of a polygon, drawn or surveyed, which encloses the area.

Contour Line.—A line joining points having or representing equal elevations.

Curved Line.—A line which changes direction at every point.

Datum Line.—A line of reference. This term is sometimes incorrectly used for "Datum Plane."

Fall Line.—A rope or steel cable used with pulley-blocks in hoisting.

Grade Line.—A line connecting grade points.

Ground Line.—The line of intersection of the vertical and horizontal planes of reference. The line showing the surface of the ground on a profile.

Guy Line.—Same as "Guy," *q.v.*

Hand Line.—A small rope used in guiding moving, suspended objects.

Horizontal Line.—Any line in a horizontal plane.

Influence Line.—A line which represents the variation of moment, shear, stress, deflection, or similar function at a particular point in the structure, due to a load of unity moving across it.

Leading Line, or Lead Line.—A line attached to the hammer in a pile driver. The line or cable which runs from the load to be lifted to the first sheave or block in a hoisting tackle.

Lead Line.—The line attached to the sounding lead for measuring the depths of water, marked in either fathoms or feet.

Load Line.—A rope or cable which carries the load. In graphic statics, the line of a force polygon on which the loads are laid off.

Meander Line.—A traverse line run along the banks of a stream so as to conform with its changes of direction and to enable it to be plotted.

Mooring Line.—A line used to fasten an object. Generally applied to a vessel or barge.

Mud Line.—The line of intersection of the mud surface with an object imbedded therein. The earth line in a profile of a river crossing.

Neat Line.—The true face line of a building regardless of the projections of the [illegible]. A line back of or inside of incidental projections.

Periphery Lines.—Lines forming the periphery of an object or figure.

[illegible]

[illegible] pass around a [illegible]

[illegible] **Line.**—The line [illegible]
ing, etc., in general, the line [illegible]
of the intersection of [illegible]

Straight Line.—The shortest [illegible]
or angles.

Tag Line, or Tail Line.—A rope attached [illegible]
A loose hanging line for guiding [illegible]
bucket.

Tie Line.—A hitching rope for a large [illegible]

Traverse Line.—Often called a "Tra[illegible]
the lengths and bearings have been [illegible]

Trip Line.—A rope by which a trip is operated [illegible]

Tow Line.—Any line used for towing.

Vertical Line.—Any line which is perpendicular [illegible]

Water Line.—The intersection of the free surface [illegible]
or object.

Lineal.—Relating to length only. Often written [illegible]

Lineal-foot.—A running foot.

Linear.—Same as "Lineal," *q.v.*

Linear Arch.—See "Arch."

Linear Velocity.—See "Velocity."

Line of Gravity.—See "Gravity."

Line of Resistance.—See "Resistance."

Lining.—The covering of the inner surface of anything [illegible]

Link.—A ring or element of a chain, a loop. Anything [illegible]
to another. To unite or connect. A crook or wind[illegible]

Repair Link.—A split link used temporarily for repairing [illegible]

Snap Link.—An open link with a movable part opening [illegible]
chains.

Link Belting.—See "Belting."

Link Block.—See "Block."

Link Chain.—See "Chain."

Link Lever.—See "Lever."

Link-motion.—In steam engines, a system of gearing for [illegible]
lating the position of the cut-off, and starting or reve[illegible]

Lintel.—A horizontal beam across an opening in [illegible]
Summer," *q.v.*

Linville Truss.—See "Truss."

Lip Washer.—See "Washer."

Liquidate.—To pay off a debt.

Liquidated Damages.—Damages determined, as to amo[illegible]
by a judgment.

—See "Load."

Stress—See "Stress."

—The weight carried by a beam, girder, truss, span, or structure [illegible] any part of such structure, including its own weight.

Load.—The load at a panel point of a truss.

Load.—The load which comes on an axle of a wagon, car, or locomotive and in turn transferred to the structure.

king Load.—A load which when placed upon a structure or test-piece should be great enough to break it.

rifugal Load.—The horizontal load on a structure produced by the centrifugal action caused by the velocity and mass of a moving train as it passes around curve.

centrated Load.—A load that is concentrated at a point or distributed over a very ll area.

ling Load.—A load which, if put on a member or a structure, will disable or aken it.

Load.—The weight of all the parts of a bridge itself and anything that may remain upon it for any length of time, such as tracks, water mains, telephone and telegraph lines, snow, dirt, moisture, etc.

entric Load.—A load which is applied to one side of the axis of resistance, and which, consequently, produces a bending moment on the piece considered.

uivalent Uniform Live Load.—A load of the same weight for each unit of its length and practically equivalent in its effect to an assumed typical live load composed of varying wheel concentrations with various wheel spacings.

cess Load.—An "Over Load," *q.v.* See also "Locomotive Excess."

ed Load.—Any determined load.

pact-allowance Load.—A percentage allowance for impact from the live load.

pact Load.—A load due to "Impact," *q.v.*

irect Wind Load.—A transferred wind load.

mit Load.—The greatest load which a structure is permitted to carry as set forth in the specifications. A safety load.

Live Load.—A moving load on a structure.

Moving Load.—An advancing load on a structure.

Over Load.—A load which produces intensities of stress beyond the allowable unit stresses.

Panel Load.—Same as "Apex Load," *q.v.*

rmanent Load.—Same as "Dead Load," *q.v.*

roof Load.—The greatest load that can be applied to a member without producing permanent distortion.

iescent Load.—A load that is not in motion.

lling Load.—Same as "Moving Load," *q.v.*

e Load.—Any load which does not produce stresses, in the members, having higher intensities than those allowed in the specifications.

tic Load.—Same as "Dead Load," *q.v.*

Test Load.—A live load applied to any finished construction as an ocular proof of its safety. It is of no real value.

action Load.—A load due to the kick back of the locomotive drivers running on the rails (equal to the draw-bar pull), or the thrust from a braked train.

sferred Load.—A load which has been carried over from another part of the structure to the member in question.

sverse Load.—A load which is applied perpendicularly to the plane of the longitudinal axis of the member or the structure, such as a wind load.

Load.—A load without a counterpoise. Refers generally to loads from motive drivers.

[illegible]

[illegible] Loads.—A [illegible]

[illegible]

[illegible] Loads.—Loads on [illegible]

their bearings.

[illegible] Loads.—A load on a

Working Load.—A safe load

Load Diagram.—See "Diagram."

Loading.—A system of loads on a structure.

Load Line.—See "Line."

[illegible] Fine.—See "Fine."

Lock.—To close and fasten in. Any [illegible] their turning. A barrier to [illegible] to a caisson shut off by two doors and [illegible] the caisson.

Nut Lock.—A device for preventing a nut

Lock Bar.—See "Bar."

Locke Level.—See "Level."

Locking Gear.—See "Gear."

Lock Joint.—See "Joint."

Lock Nut.—See "Nut."

Lock Nut Washer.—See "Washer."

Lock Pit.—See "Pit."

Lock Sleeve.—See "Sleeve."

Locomotive.—A steam engine which travels on engine designed and adapted to travel on a

American Locomotive.—A passenger locomotive no trailer wheels.

Atlantic Locomotive.—A passenger locomotive trailer wheels.

Back Truck Locomotive.—A locomotive having a its rear end as well as a truck in front of the

Belgian Tank Locomotive.—A locomotive having

Compound Locomotive.—A freight locomotive times four) on each side, in which the steam is to cylinder.

Consolidation Locomotive.—A freight locomotive and no trailer wheels.

Dinkey or Dinky Locomotive.—Any small locomotive which runs on a narrow-gauge track. Used largely

Double Ender Locomotive.—A locomotive having engines.

Double Piston Locomotive.—A locomotive in which with rods projecting from each end, and working from each other.

Double Truck Tank Locomotive.—A locomotive which boilers and tenders on a single frame.

Electric Locomotive.—A locomotive run by an electric

Fireless Locomotive.—A locomotive driven by compressed from highly heated water carried in strongly constructed

Four-cylinder Locomotive.—A locomotive having four of driving wheels.

Freight Locomotive.—Any heavy locomotive which one with heavy wheel concentrations and small driving

otive.

ed Locomotive.—A locomotive in which the motion of the engine is conveyed by gearing to the drivers.

et Locomotive.—A heavy freight locomotive having two sets of six, eight, or ten driving wheels each.

kado Locomotive.—A heavy locomotive having two pilot, eight driving, and two trailer wheels.

ogul Locomotive.—A type of freight engine with three coupled driving wheels on each side and a swinging, two-wheeled truck in front.

ountain Locomotive.—A heavy locomotive having four pilot, eight driving, and two trailer wheels.

acific Type Locomotive.—A locomotive having four pilot wheels, six driving wheels, and two trailers.

assenger Locomotive.—A locomotive having large drivers used for hauling passenger cars.

Prairie Type Locomotive.—A locomotive having two pilot, six driving, and two trailer wheels.

hay Locomotive.—A geared locomotive.

witching Locomotive.—A locomotive used mainly for switching cars in the yards.

Tank Locomotive.—A locomotive permanently connected with its tender.

en-Wheeled Locomotive.—A locomotive with six coupled driving wheels, and a four-wheeled truck in front of the drivers.

comotive Balance.—A spring used in place of a weight to control the safety valve of a locomotive.

omotive Boiler.—See "Boiler."

omotive Car.—See "Car."

omotive Crane.—See "Crane."

omotive Diagram.—See "Diagram."

omotive Driver.—See "Driver."

omotive Excess-load.—An early method for computing stresses in a span by the use of a uniform carload with one or more engine excesses. No longer employed in American bridge designing.

ouble Locomotive Excess-Load.—A live load composed of a uniform carload per lineal foot preceded by one concentrated load and followed by another about fifty feet behind, or the length of a locomotive with its tender. This loading is no longer used in American bridge engineering.

ingle Locomotive Excess-load.—A live load in which a single concentration is followed by a uniform car load.

omotive-pilot.—The truck and its wheels set in front of the drivers of a locomotive.

omotive Pump.—See "Pump."

us.—In mathematics, a curve considered as generated by a moving point, or a surface considered as generated by a moving line; the partly indeterminate position of a point subject to an equation or to two equations in analytic geometry; a curve considered as generated by its moving tangent or by a moving curve of which it is the envelope; any system of points, lines, or planes defined by general conditions, and, in general, partly indeterminate.

.—An abbreviation for "Logarithm," *q.v.* A bulky piece or stick of timber.

arithm.—The exponent of the power to which a fixed number, called the base, must be raised in order to produce a given number.

s' Logarithm or Common Logarithm.—A system of logarithms in which the base is ten.

perbolic Logarithm, or Naperian Logarithm, or Natural Logarithm.—A system of logarithms in which the base is 2.71828+.

Curve.—See "Curve."

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] Girder.—See "Girder."

[illegible]

Longitudinal Section.—See "Section."

Longitudinal Shear.—See "Shear

Longitudinal Stress.—See "Stress."

Longitudinal Thrust.—See "Thrust,"

Longitudinal Tie Girder.—See "Girder."

Long Leaf Yellow Pine.—See "Pine."

Long Ton.—See "Ton."

Loop.—A folding or doubling of a string, fasten or secure with loops. A knot bar or ring at each side of any piece of ment of another part. An elongated eye is

Bent Loop.—A loop eye-bar in which the loop the length of the bar.

Loop Eye.—See "Eye."

Loop Tackle.—See "Tackle."

Loose Joint.—See "Joint."

Loose Knot.—See "Knot."

Loricated Pipe.—See "Pipe."

Lorry.—An English term for a tramway wagon, platform and four small wheels used for it is used to denote a motor truck and also drop-bottomed car running on a track, such as spelled "Larry."

Lorry Rail or Lorry Track.—See "Track."

Low Bridge.—See "Bridge."

Lower Chord.—Same as "Bottom Chord." See "Chord

Lower Deck.—See "Deck."

Lower Falsework.—See "Falsework."

Lower Lateral Bracing.—See "Bracing."

Lower Laterals.—See "Laterals."

Low Steel.—See "Steel."

Low Water.—See "Water."

Low Water Mark.—See "Water."

Lubricant.—Any material used on rubbing surfaces to also the resistance to motion.

Lubricate.—To reduce the friction of two surfaces the position of oil or other material so as to lessen the moves on the other.

Lubrication.—The act of lubricating; the state of being

Luff.—To bring a vessel into the wind. To swing the

Luff Tackle.—See "Tackle."

Lug.—Any kind of a projection for carrying or supporting something.

Angle Lug.—Same as "Clip Angle." See "Angle."

Lug Angle.—Same as "Clip Angle." See "Angle."

Lug Bolt.—See "Bolt."

Lug Hook.—Same as "Lug Bolt." See "Bolt."

Lumber.—Timber that has been sawed or split for use.

Lumber Kiln.—See "Kiln."

Lump-sum.—An adjective applied to the method of paying for different kinds of work, all lumped together as one unit. A single payment.

Luster.—A term used in describing the character of the reflections obtained from the fractured surfaces of minerals and from the broken ends of metal test-pieces.

Lute.—A mixture of fire-clay, used to seal cracks when heat is applied.

M

Macadam.—A type of pavement consisting of broken stone laid in courses and rolled.

MacArthur Pile.—Same as "Pedestal pile." See "Pile."

Machine.—An apparatus, instrument, or mechanical element for the transmission of force and the conversion of motion.

Machine Bolt.—See "Bolt."

Machine Chain.—See "Chain."

Machine Drill.—See "Drill."

Machine Finish.—See "Finish."

Machine-made.—Made by a machine; used in contra-distinction to hand-made.

Machinery.—A general term used collectively for a number of machines.

Supporting Machinery.—Machinery used in connection with the operation of a lift span.

Machinery Barge.—See "Barge."

Machinery House.—A house in which machinery is kept for its protection.

Machine Screw.—See "Screw."

Machine Shop.—See "Shop."

Machine Work.—See "Work."

Machinist Hammer.—See "Hammer."

Magnesian Lime.—See "Lime."

Magnesian Limestone.—See "Limestone."

Magnetic.—Having properties like those of a magnet—possessing magnetism.

Magnetic Needle.—See "Needle."

Main Diagonal.—See "Diagonal."

Main Member.—See "Member."

Main Shaft.—See "Shaft."

Main Stress.—See "Stress."

Maintenance Cost.—See "Cost."

Making Iron.—An iron with rounded teeth, used for driving home a strand of oakum.

Male Screw.—See "Screw."

Malleable.—Capable of being shaped by a beating or rolling process.

Malleable Cast Iron.—Same as "Malleable Iron." See "Iron."

Malleable Iron.—See "Iron."

Malleable Pig.—See "Pig."

Mallet.—A small wooden hammer wielded with one hand.

Calking Mallet.—A mallet used in driving calking irons.

Mallet Locomotive.—See "Locomotive."

Mandrel, or Mandril.—A short shaft of uniform or varying diameter upon which various pieces of metalwork can be mounted for turning in a lathe. A metallic core used in driving Raymond or Simplex piles.

[illegible]

[illegible] and [illegible]

[illegible] Steel.—See "[illegible]

Mangle.—A set of rolls for

Mannheim Slide-rule.—See "

Man-hole.—An opening or entrance by which

a boiler, sewer, or conduit.

Manifold.—A tube, usually of

inlets and two or more

main a number of supplies of

Manila Hemp.—See "Hemp."

Manila Rope.—See "Rope."

Man-power.—The power exerted by a man.

his power to advantage.

Map.—A descriptive drawing or delineation

Hydrographic Map.—A map showing a

dicating the depth of water at various

current, the character of bed and bank,

special stream.

Topographic Map.—A map showing the

lines of equal elevation.

Margin.—A space along an edge or boundary

Margin Draft.—See "Draft."

Marking Gauge.—Same as "Hand Gauge."

Marline.—A small rope made of two strands

around ropes, cables, etc.

Marline Spike.—See "Spike."

Masonry.—A general term applied to structures

Ashlar Masonry.—Stone masonry composed of

rectangular, laid in courses of uniform height.

Brick Masonry.—Masonry composed of brick,

Broken-ashlar Masonry.—An ashlar masonry in

at intervals, due to the use of smaller blocks of

Broken-range Masonry.—A range type of

continuous throughout, due to their being made

of stone.

Concrete Masonry.—Masonry composed of concrete

Crandalled Masonry.—Any type of masonry in which

with a crandall. See "Dressing."

Cut-stone Masonry.—Any type of masonry composed

smoothly dressed beds and joints.

Doweled Masonry.—Masonry in which dowel pins

courses together and thereby prevent sliding.

Dry Masonry.—Masonry in which the stones are laid

First-class Masonry.—A term applied to quarry-faced

zontal courses, having parallel beds and vertical joints

in thickness nor more than thirty, and decreasing

bottom to the top of the wall. For complete specifications

Granite Masonry.—Masonry composed of granite blocks

Green Masonry.—Masonry freshly laid, in which the

strength.

Random Masonry.—Masonry composed of blocks

varying size and not laid in courses.

ry.

ge Masonry.—Masonry composed of blocks having squared joints and which are laid in courses varying in thickness.

bble Masonry.—Masonry composed of unsquared stone. It may be coursed or uncoursed rubble.

cond-class Masonry.—A term applied to broken range rubble of superior quality laid with horizontal beds and vertical joints on the face, with no stone less than eight inches thick, well bonded, and leveled as well as can be done without hammer dressing.

all-ashlar Masonry.—Cut-stone masonry in which the stones are less than one foot thick.

quared-range Masonry.—Masonry composed of squared stones laid in ranges or courses of varying thickness.

uared-stone Masonry.—Masonry composed of stones roughly dressed and squared on beds and joints. Similar to ashlar masonry, but not having as close joints.

ird-class Masonry.—A term applied to rubble when of a good, substantial quality and laid in cement mortar.

ry Joint.—See "Joint."

ry Pier.—See "Pier."

ry Plate.—See "Plate."

ry Stone.—See "Stone."

onry Wall.—See "Wall."

on's Hammer.—See "Hammer."

.—The quantity of matter in a body. It is measured by the ratio of its weight to the acceleration due to gravity.

enter of Mass.—That point at which the mass of a body may be considered as concentrated without disturbing its equilibrium; the center of gravity or the center of inertia of a body.

t.—An upright post of timber or steel, as the mast of a derrick.

errick Mast.—The upright member of a derrick, at the bottom of which the boom is attached and which is pivoted so as to allow the boom to swing either way.

ic.—A well-agitated mixture of several different small-grained constituents, one of which has a cementing or binding power.

phaltic Mastic.—A mastic composed of refined asphalt and other constituents, melted together at a temperature between 275° and 400° F., and thoroughly agitated by suitable appliances until the materials are completely blended into a homogeneous mass; sometimes referred to as Asphaltic Cement.

Pin.—See "Pin."

Seat.—The casting at the foot of a mast on which it rests and turns.

—Same as "Mattress," *q.v.*

ing.—A fitting together of two or more parts.

Joint.—Same as "Tongue and Groove Joint." See "Joint."

-marking.—A system of marking the parts or members of a structure, so that they always may be connected up in exactly the same order and manner.

ial.—Any substance entering into the construction of a bridge.

—A term used in connection with concrete to denote the cementing material which fills the voids of the aggregate.

.—A form of pick with broad cutting edges for digging.

—A combination of willow poles and wire rope woven together, forming a mat which is placed on the bed or the bank of a stream to prevent scouring.

—See "Work."

type of large hammer or mallet having both ends flat for beating.

Maul.—An iron maul heavier than a calking mallet.

[illegible]

[illegible]—The science of force [illegible] used to [illegible] the doctrine of forces and the [illegible] and systems of particles. [illegible] sciences.

Mechanism.—The structure of a machin [illegible] or utilising natural forces.

Medium Steel.—See "Steel."

Megohm.—An electrical unit of resistance

Melan Arch.—See "Arch."

Melt.—To fuse or liquify by applying heat. A denote the metal fused, or the charge

Dead Melt.—In the fusion of metals, a conditi and in which no gas is being evolved.

Melting-point.—The temperature at which a state.

Melt-numbers.—The number given a heat or out the processes of rolling and fabrication

Member.—A component part of a bridge or other

Adjustable Member.—A member of a bridge, the or diminished at will.

Main Member, or Primary Member.—A princip generally restricted to trusses.

Redundant Member.—A superfluous member. in the most approved American bridge-engineeri

Secondary Member.—A subordinate part of a bridge to the suspenders and sub-diagonals of trusses.

Secondary Truss-Member.—A subsidiary member or to transfer a load from a mid-panel point to a

Tension Member.—A member of a structure subjected

Truss Member.—Same as "Truss Element." See

Web Members.—The parts or sections forming the web

Merchants' Bar.—See "Bar."

Meridian Section.—See "Section."

Mesh.—An open space between the wires of a screen or the netting composed of wires. Also used to denote another.

Metacenter.—The point of intersection of a vertical line and a line of symmetry through the center of gravity

Metal.—As used in bridgework, this term means steel, unless

Babbitt Metal.—An alloy of tin with copper and ant and making bushings.

Metal.

Calking Metal.—A soft lead-rust mixture put in calking grooves. Sometimes Portland cement is used for such purpose.

Fatigue of Metals.—The doctrine which states that repetitions or reversals of stress, when excessive, cause a deterioration of the metal. Strictly speaking, it does not apply at all to bridgework.

Gun Metal.—Same as "Bronze," *q.v.*

Pin Metal.—The metal called for in the specifications, from which pins may be made.

Pot Metal.—A poor grade of cast iron.

Sterro Metal.—A brass containing from 1.77% to 4% of iron.

White Metal.—An alloy similar to Babbitt metal, but containing more antimony and copper.

Metal Lath.—See "Lath."

Metal Lathe.—See "Lathe."

Metallic Tape.—See "Tape."

Metal Saw.—See "Saw."

Meteoric Iron.—See "Iron."

Meter.—A unit of length in the metric system which equals 39.37 inches in the English and American systems. An apparatus for measuring quantities.

Current Meter.—An apparatus for measuring the velocities of flow in streams.

Water Meter.—An apparatus for measuring the quantity of water flowing in a pipe.

Metope.—A square slab, decorated or plain, inserted in the opening between adjoining ceiling beams.

Metric System.—A system of units of weights and measures depending upon the meter. It is the standard in Continental Europe and in Latin America, and ought to be adopted throughout the entire world.

Metric Ton.—See "Ton."

Micrometer.—An instrument for the precise measurement of small lengths and angles. The usual form consists of a screw with a very fine thread and a large graduated head.

Touch Micrometer.—A micrometer in which the final adjustment is determined by the sense of feeling.

Micrometer Calipers.—See "Calipers."

Micrometer Gauge.—Same as a "Micrometer Calipers." See "Calipers."

Micrometer-measurement.—A precise determination of the diameter of a test piece by a micrometer-screw.

Micrometer Screw.—Same as "Micrometer," *q.v.*

Middle-third.—A term in masonry construction used in connection with the line of pressure to denote a condition which must obtain in order to prevent tension at a joint of the structure; that is, the line of pressure must pass within the middle third of the section.

Mid-span.—The centre of a span.

Mikado Locomotive.—See "Locomotive."

Mild Steel.—See "Steel."

Mill.—A machine for rolling plates, shapes, rails, etc. The plant where steel shapes etc., are rolled. To remove metal by a circular tool having teeth as in a milling machine.

Boring Mill.—A large machine tool having a horizontal revolving table to which the object to be trimmed is fastened, and in which the cutting tool, except for feed adjustment, remains fixed in position while the object revolves. Used for turning large castings and boring large holes.

Cement Mill.—A factory where cement is manufactured.

Universal Mill.—A four-roll mill for rolling plates on both edges as well as on the faces.

[illegible]—Same as “[illegible]

[illegible]

[illegible] Machine.—A machine [illegible]

cutter and a movable table, [illegible]

to be milled.

Mineral Paint.—See “Paint.”

Mirror Iron.—See “Iron.”

Miter.—To cut at a bevel of forty-five degrees

Miter Gears.—See “Gears.”

Miter Joint.—See “Joint.”

Mixer.—A machine for mixing materials.

Concrete Batch Mixer.—A type of mixer in
desired proportions for a definite amount of
before a fresh supply of materials is entered.

Concrete Continuous Mixer.—A type of mixer
their respective hoppers and then
frequent and regular intervals into a
the content is continually being forced into the

Modulus.—A number, coefficient, or quantity that

Section Modulus.—See “Section Modulus.”

Modulus of Crushing.—See “Crushing.”

Modulus of Elasticity.—See “Elasticity.”

Modulus of Rupture.—See “Rupture.”

Mogul Locomotive.—See “Locomotive.”

Molecule.—The smallest part into which any
ing its chemical character.

Moment.—The tendency of a force to produce rotation
to resist rotation. This tendency is measured by
lever arm.

Bending Moment.—The moment which produces or
a beam or other member of a structure. It is
the products of all the forces by their respective

Centre of Moments.—The point about which a body
arbitrarily chosen for convenience in determining the
of forces.

Horizontal Moment.—A moment acting in a horizontal

Negative Moment.—A relative term used to denote
taken counter-clockwise.

Overturning Moment.—The moment of the external
a structure.

Positive Moment.—A moment acting in the opposite
or acting clockwise.

Resisting Moment.—The moment which opposes
turning Sometimes loosely used for moment of

Righting Moment.—The moment that tends to right a
ment.

Theorem of Three Moments.—A theorem used in
expressing the relation of the moment at any support
ceding and following supports in terms of the loading

Twisting Moment.—Same as “Torque,” *q.v.*

Virtual Moment.—See “Virtual.”

Moment-area.—Same as “Area-moment.” See “Area.”

Moment-area Method.—The method for finding
use of the moment area curve.

Diagram.—See "Diagram."

of a Couple.—See "Couple."

of Inertia.—See "Inertia."

of Resistance.—See "Resistance."

ent of Stability.—See "Stability."

ment of Torsion.—See "Torsion."

entum.—The quantity of motion in a body, measured by the product of its mass into its velocity.

nier Arch.—See "Arch."

nier-Construction.—A form of reinforced concrete in which wire netting is used for reinforcement.

key.—An early type of pile-driver hammer.

key Engine.—See "Engine."

key Pile Driver.—See "Pile Driver."

key Wrench.—See "Wrench."

ing.—A fastening; that to which anything is fastened.

r.—A mixture of cement or lime with sand and water forming a thick paste, used in masonry work for bedding the stones and filling the joints.

ing of Mortar.—Mortar placed by compressed air forcing it through a pipe or nozzle.

ement Mortar.—A mortar made from cement.

ydraulic Mortar.—Mortar made of hydraulic cement, so that it will set under water.

ime Cement Mortar.—A mortar in which lime and cement are used together. Not a proper mixture for bridge construction, the only reason for its use being to reduce first cost, which it invariably does at the expense of the effectiveness of the construction.

e Mortar.—A mortar made from lime. Should never be used in bridgework.

empering Mortar.—The wetting and stirring up of mortar after partial setting. A most reprehensible practice.

pering Mortar.—The mixing and working of mortar to secure a uniformly plastic ondition.

r-board.—A platform on which mortar is mixed.

r-box.—See "Box."

e.—The slot or hole cut in a timber to receive the tenon.

sed Joint.—See "Joint."

r.—A machine for producing or translating power.

ctric Motor.—A motor run by an electric current.

Bridge.—See "Bridge."

rway.—The passageway on a bridge used by motor cars.

d Iron.—See "Iron."

d.—A form or model pattern of a particular shape, used in fixing the shape of a plastic mass. Sometimes spelled "Mold."

uette Mould.—A standard form used for making briquettes out of mortar.

ent Mould.—A mould used in forming cement mortar for testing purposes.

Mould.—A flask in which metal is cast into a large block or ingot.

ed Gear.—Same as "Cast Gear," *q.v.*

ng.—The process of shaping a plastic substance into a given form by the use moulds. Also a decorative member in construction.

g Planks.—See "Planks."

n Locomotive.—See "Locomotive."

ng.—A string or wire wound around the end of a rope to prevent raveling.

e Bridge.—More correctly speaking, a movable span. See "Span."

Cofferdam.—See "Cofferdam."

Span.—See "Span."

[illegible]—A device to prevent the [illegible]

[illegible]

[illegible].—See "[illegible]"

[illegible] Arch.—See "Arch."

Multiple [illegible].—See "[illegible]"

Multiple Intersection.—Same as "[illegible]"

Multiple Punch.—See "Punch."

Multiple System.—A truss system [illegible]
than two systems of [illegible]

Multiple Truss.—See "Truss."

Murphy Truss.—See "Truss."

Mushet Steel.—A steel produced by the [illegible]
consists of adding spiegel or other [illegible]

Mushroom Anchor.—See "Anchor."

[illegible].—The condition of a casting [illegible]
rendering it unsound.

N

Nail.—A slender piece of metal either pointed [illegible] wood or other material. Nails run in size [illegible] 20d (twenty penny), four inches long [illegible] up to 60d (sixty penny), or six inches long,

Calking Nail.—A pointed hand-tool used in

Cut Nail.—A nail which is cut from a plate.

Wire Nail.—A nail made from wire.

Wrought Nail.—A nail hammered out from a bar.

Nail-extractor.—A hand-tool for pulling nails.

Nail-head Spike.—See "Spike."

Nailing-blocks.—Blocks of wood inserted in walls of [illegible] boards to.

Name Plate.—See "Plate."

Naperian Logarithm.—See "Logarithm."

Nasmyth's Steam Hammer.—See "Hammer

Natural Bar.—See "Bar."

Natural Bed.—See "Bed."

Natural Cement.—See "Cement."

Natural Logarithm.—See "Logarithm."

Natural Scale.—See "Scale."

Nave.—The hub of a wheel.

Neat.—Pure; undiluted; unadulterated. Also someti

Neat Briquettes.—Same as "Cement Briquettes," *q.v.*

Neat Cement.—See "Cement."

Neat Lime.—See "Lime."

Neat Line.—See "Line."

Neat Work.—See "Work."

Neck.—That part of a test specimen, subjected to tension, which shows a reduction of area of cross-section when the ultimate load is reached. To reduce suddenly the sectional area of a piece of metal. To nick.

Necking-down.—The act of reducing the cross-section of a test specimen by stressing it beyond the yield point.

Neck Journal.—See "Journal."

Needle.—A very small steel rod or bar.

Cement Needle.—A small round rod weighted with a ball, used to determine the activity of cement.

Magnetic Needle.—A thin, small bar of magnetized steel used in a surveyor's compass to determine the magnetic meridian at any place.

Vicat Needle.—A small rod, one millimeter in diameter, mounted in a frame and bearing a weight of three hundred grams; used for testing the activity of cement.

Needle Beam.—See "Beam."

Negative Moment.—See "Moment."

Negative Print.—See "Print."

Negative Reaction.—See "Reaction."

Negative Rotation.—See "Rotation."

Negative Shear.—See "Shear."

Nest (of rollers).—A group of rollers, enclosed in a suitable frame or box, which support a bridge shoe.

Net.—Clear of anything extraneous. Lowest or smallest. Not subject to any further deduction or correction. Netting.

Netting.—A wire mesh-work used somewhat in reinforced-concrete construction, especially for piling.

Net Section.—See "Section."

Neutral Axis.—See "Axis."

Neutral Curve.—See "Curve."

Newel Post.—See "Post."

New York Rod.—A type of level rod. See "Rod."

Nickel Steel.—See "Steel."

Nidging or **Nigging.**—A form of stone dressing. See "Dressing."

Niggerhead.—A spool on the end of the axle of a hoisting engine.

Night Foreman.—See "Foreman."

Night Superintendent.—See "Superintendent."

Nipper.—A block which slides in the leads of a pile driver and carries a pair of hooks or tongs for picking up the hammer below it.

Nipper Pile Driver.—See "Pile Driver."

Nipple.—A short piece of pipe threaded throughout its entire length.

Nodule.—A small lump.

Nog.—Same as "Free-nail," *q.v.*

Nominal Horsepower.—Same as "Commercial Horsepower." See "Horsepower."

Non-concurrent.—Applied to non-parallel forces not having a common point of intersection.

Non-fusibility.—The ability to resist fusing.

Non-volatile Thinner.—See "Thinner."

Non-volatile Vehicle.—See "Vehicle."

Normal Stress.—See "Stress."

Norway Iron.—See "Iron."

Norway Pine.—See "Pine."

Nose.—A pointed or tapering projection in front of an object., *e.g.*, the nose of a pier that acts as an ice-break.

Nosing.—The end of a pier. See "Starling." The projection on the front edge of a step.

[illegible]

[illegible]—A short piece of metal having
or a screw.

Beam Hanger Nuts.—The nuts on the
floor-beams against the foot of the

Check Nut.—An extra nut which is
prevent the latter from working loose

Driving Nut.—A special, flat-headed,
end of a pin to receive the blows of
pin home.

Hexagonal Nut.—A nut having six equal

Jam Nut.—Same as "Check Nut," *q.v.*

Left-handed Nut.—A nut having a left hand

Lock Nut.—A nut having some special provision

Lomas Nut.—A nut having a recess on the
down on the pin until the edges of the nut
said pin.

Pilot Nut.—A round nut, having one end
order that it may be pushed through the
members meeting at a panel point. After
removed, and a Lomas nut is screwed on in

Pin Nut.—A special flat nut used on truss pins.

Right-handed Nut.—A nut having a right-hand

Sleeve Nut.—A sleeve having a right-hand thread
at the other.

Square Nut.—A nut having four sides in the form

Thumb Nut.—A nut having a flat projection,
the thumb and finger.

U-Nut.—A piece of iron or steel in the shape
the threaded end of a rod, and which affords a
screw up the latter. Its use is not permissible in

Wing Nut.—Same as "Thumb Nut," *q.v.*

Nut-cracker.—A tool for breaking the nuts on rusty

Nut Lock.—See "Lock."

O

Oakum.—The coarse part of flax or hemp separated
twisted and picked into loose fibres resembling
of vessels and caissons.

Oblique Arch.—See "Arch."

Oblique Crossing.—See "Crossing."

Ochre.—A term applied to a class of natural earths
hydrated sesquioxide of iron with various earthy
alumina. Many of these earths are used for pigments

Red Ochre.—A variety of ochre having a red color,

Yellow Ochre.—A variety of ochre having a yellow

Octagon.—A regular eight-sided polygon.

Odometer.—An instrument for measuring distance by
The circumference of the wheel is accurately
attached so as to register the number of revolutions

Offset.—A short line run at right angles to a principal, or base, line. To move over from a base line to an auxiliary line called an offset line.

Ogee Curve.—See "Curve."

Ogee Washer.—See "Washer."

Ohm.—The unit of electrical resistance; approximately the resistance of one thousand feet of No. 10 B. & S. copper wire.

Oil Bearing.—See "Bearing."

Oil Boxes.—See "Boxes."

Oil Can.—A can having a long tapering spout, used for pouring oil into bearings.

Oil Groove.—See "Groove."

Oil Hardening.—The process of quenching red-hot steel in oil in order to harden it.

Oil-hole.—A hole drilled in the cap of a bearing for pouring oil through.

Oil-stone.—A slab of fine-grained stone used for sharpening tools by rubbing them on its oiled surface.

Oil Tempering.—See "Tempering."

Old English Bond.—See "Bond."

Old-man.—An iron frame bent into the form of a U having hooks on the ends so that it can be hung to a bar, a rail, or the flange of a girder and used to form a bearing for a ratchet drill or reamer.

One Hingod Arch.—See "Arch."

One-man Stone.—A rough classification for stone of a size that can be readily lifted and put into place by one man. Used to reduce the cost of concrete.

Oölitic Limestone.—See "Limestone."

Opacity.—The degree of obstruction to the transmission of visible rays. Used in connection with paint.

Open Caisson.—See "Caisson."

Open Crib.—See "Crib."

Open-dredging.—A process of sinking piers by excavating with a dredge through an open crib.

Open-end Wrench.—See "Wrench."

Open Hearth.—The hearth of a metallurgical furnace which is exposed to the direct action of the flame.

Open-hearth Furnace.—See "Furnace."

Open-hearth Process.—A process for the production of steel by the oxidation and removal of the impurities contained in a bath of metallic iron lying on the hearth of a regenerative furnace.

Acid Open-hearth Process.—That process of producing steel from pig and scrap iron, in which the first step is to remove most of the silicon, manganese, and carbon from the molten mass. Just before tapping, spiegeleisen or an artificial ferromanganese is added to the charge in order to destroy the oxide slag and prevent red shortness. The furnace is lined with a silicious material.

Basic Open-hearth Process.—That process of producing steel from pig and scrap iron, in which the first step is to remove the phosphorus and some of the sulphur as well as the silicon, manganese, and carbon. This is accomplished by charging the furnace with calcined lime, which unites with the excess phosphorus and holds it in the slag. The rest of the process is similar to the acid open-hearth process. To prevent the slag from attacking the lining, the furnace is covered with dolomitic limestone. Such furnaces are termed basic lined, and the process has become known as the basic open-hearth process because of this lining.

Open-hearth Steel.—See "Steel."

Open Holes.—Rivet holes in members and connections left open during fabrication to enable the erector to connect the parts in the field, after which field rivets are driven into them.

Open Joint.—See "Joint."

[illegible]

[illegible]—A general term for [illegible]

[illegible]—A vibratory movement of any [illegible]

[illegible]—See "Guardrail." [illegible]

[illegible]—See "Hip." [illegible]

[illegible]—A method used by [illegible] reach of the boom of the derrick. It [illegible] member beyond the derrick and doubling [illegible]

Outline.—The exterior line defining the [illegible]

Out of Gear.—A condition in a system of [illegible] mesh with the driven gear and, in [illegible]

Out of Square.—Askew, oblique. [illegible]

Out of Wind.—Free from twist; not warped.

Output.—The production of a mill, plant, or [illegible]

Outrigger.—A beam or joist projecting from a [illegible] end.

Outrigger Hoist.—See "Hoist."

Outside Calipers.—See "Calipers."

Outside Lock Tender.—See "Tender."

Outside Stringers.—See "Stringer."

Oval.—A closed curve, everywhere convex, with [illegible] curvature at one end than at the other.

Overblown.—A term applied to Bessemer steel which [illegible] overoxidized and hence inclined to be wild.

Overhang Knot.—See "Knot."

Overhaul.—The excess haul or movement of earth or [illegible] named in the contract. To examine thoroughly [illegible] up slack in a rope by pulling thereon.

Overhead Balanced Crane.—See "Crane."

Overhead Bracing.—See "Bracing."

Overhead Crane.—See "Crane."

Overhead Crossing.—See "Crossing."

Overhead Girder.—See "Girder."

Overhead Strut.—See "Strut."

Overheat.—To heat metal to a temperature near the [illegible] coarse grained and reducing the cohesion between [illegible]

Overlap.—To extend over and rest upon; to fold over [illegible]

Overlapping Joint.—See "Joint."

Overload.—See "Load."

Overmelt.—To keep steel too long in a state of fusion [illegible]

Overtime.—The excess time over the regular schedule [illegible]

Overturning Moment.—See "Moment."

Ovolo.—A projecting convex moulding of a quarter of a circle in section.

Oxide of Iron.—Same as "Iron Oxide," *q.v.* Also see "Ochre."

P

Pacific Type Locomotive.—See "Locomotive."

Pack.—To arrange eye-bars on a truss pin. To insert some pliable or elastic material in a stuffing box around a moving rod so as to produce a water-tight, air-tight, or steam-tight connection.

Packing.—The arrangement of the component parts of a member. The material used in packing a piston rod, etc. The arrangement of bars and other members on a pin.

Asbestos Packing.—Packing made from asbestos fibre and put up in the form of wicking.

Candle-wick Packing.—A packing made of cotton fibres and put up in the form of a loosely-woven cord.

Chord Packing.—The arrangement of all the members of a pin-connected chord.

Hemp Packing.—Packing made of hemp fibres and put up in the form of a soft, loosely-woven rope.

Journal Packing.—Waste, cotton, or other fibrous material saturated with oil or grease and placed in a journal box to lubricate the axle.

Jute Packing.—Packing made of jute fibres and put up in the form of a soft, loosely-woven rope.

Rubber Packing.—Packing made of rubber, usually with cloth backing or insertions. Put up in sheet form or in flexible bars.

Sheet Packing.—Any packing put up in the form of thin layers.

String Packing.—Any packing put up in the form of cords.

Stringer Packing.—The arrangement of stringers under a track on a trestle.

Wick Packing.—Any packing put up in the form of wicks.

Packing-block.—A small member, generally of wood, used to retain the parts of a composite member in their proper relative positions.

Packing Bolt.—See "Bolt."

Packing Box.—Same as "Stuffing Box." See "Box."

Packing Diagram.—See "Diagram."

Packing-pieces.—Short pieces, inserted between two others which are riveted or bolted together, to prevent their coming in contact with each other.

Packing Ring.—See "Ring."

Packing Spool.—Same as "Separator," *q.v.*

Packing Washer.—See "Washer."

Peane Hammer.—Same as "Peen Hammer." See "Hammer."

Paint.—A mixture of pigment with a vehicle intended to be spread in thin coats on a surface for its protection, or its decoration, or both.

Graphite Paint.—A paint in which graphite is used for the pigment.

Mineral Paint.—Any paint in which a mineral pigment is used.

Water-proof Paint.—Any paint not soluble in water.

Paint-brush.—Any brush used for applying paint.

Painter's-torch.—A torch burning gasoline or gas under pressure produced by forcing air into the reservoir. Used for burning off old paint.

Paint-skins.—The residue in paint formed by the evaporation of the oil. Used for filling small voids in metalwork before applying the paint.

Pale Brick.—See "Brick."

Pall.—A dog in a ratchet for preventing backward motion.

Pallet.—A board on which green bricks are carried to the drying place. A cast-iron tool with chilled faces; used in forging. Also same as "Pall," *q.v.*

Palmer Truss.—See "Truss."

[illegible]

[illegible] the truss.

[illegible] Length.—See "Length."

[illegible] Load.—Same as "Axle Load."

[illegible] Point.—The point at which

axis of a chord of a truss.

[illegible]—Small pans or cups.

Pantograph.—An instrument for the

etc., either to an enlarged or

sticks pivoted so as to form a

the group, a tracing point at the

apex.

Paper.—A material composed of vegetable

or draw on, etc.

Asbestos Paper.—A paper made from

Blue Print Paper.—A paper coated

ferrocyanide which is sensitive to

Calculation Paper.—A paper with

convenience in drawing sketches and

form.

Cold-pressed Paper.—A drawing paper

leaving it with a rough surface.

Coordinate Paper.—Paper ruled into small

for convenience in counting or in tracing

Cross-section Paper.—A standard quadrille

are one inch on a side and the secondary

side.

Detail Paper.—A tough paper used for pencil

Egg-shell Paper.—A heavy drawing paper

the surface of an egg-shell.

Hot-pressed Paper.—A variety of drawing

heated plates.

Profile Paper.—A standard, double-ruled paper in

is a multiple, usually five, of the scale in the

Tarred Paper.—A paper saturated or coated

Tracing Paper.—A thin, tough, translucent

Whatman's Paper.—A trade name for a well-known

factured by the Whatman Turkey Mills.

Parabola.—A plane curve such that the distance of

called the focus, is equal to the distance of the

line, called the directrix. Also the curve formed

plane with a cone when parallel to an element of

the equation $y^2 = 2\,p\,x$.

Parabolic Chord.—See "Chord."

Parabolic Formula.—Any formula having the form

Parabolic Truss.—See "Truss."

Paraffine.—A whitish, waxy substance obtained by the

bituminous coal, wax, crude petroleum, etc.

from methane.

Parallel.—A condition of being everywhere equidistant

lines and planes.

gram.—A four-sided geometrical figure having the opposite sides parallel and al.

gram of Forces.—A name given to a method of determining the resultant of forces, acting in the same plane, by constructing a parallelogram having sides ual and parallel respectively to the forces; whereupon, the diagonal of the paral gram will represent in magnitude and direction their resultant.

piped.—A prism having parallelograms for bases.

ruler.—A draftsman's instrument for drawing parallel lines, consisting of two milar rulers connected by equal, parallel links pivoted at their ends, enabling the ges of the rulers to be spread apart a varying distance.

or Parapet Wall.—A low wall or barrier placed on top of an abutment to hold k the earth from encroaching on the end of the span.

—To wrap canvass or rags around a rope.

Cement.—See "Cement."

Truss.—See "Truss."

Splice.—See "Splice."

Pulley.—Same as a "Split Pulley." See "Pulley."

f the First Part.—A legal term for designating one of the parties executing a ntract, usually the purchaser.

f the Second Part.—A legal term for designating one of the parties executing a tract, usually the seller.

ger Locomotive.—See "Locomotive."

ster.—An instrument for registering the number of steps taken by a pedestrian. Called also a "pedometer."

Lime.—See "Lime."

—A small, flat cake of cement mortar with the edges thinned out; used in cement sting to determine its soundness or freedom from cracking.

Hammer.—See "Hammer."

Hammer Dressing.—See "Dressing."

—The base of a column or pillar. The sole for the foundation of a wall.

—A model made of wood to duplicate the desired object. It is used to form e cavity in a mould into which the molten metal is afterward poured.

n Shop.—See "Shop."

ent.—A surface covering for a roadway.

—Regularly placed stone, brick, or wood blocks forming a floor.

Brick.—See "Brick."

—A short bar pivoted at one end and engaging a toothed wheel at the other, thereby preventing a backward rotation. Also spelled "Pall," *q.v.*

—To cover a surface with tar or pitch, etc.

—To slacken or let out rope.

—A projecting point; a cusp in a curve.

Hammer.—See "Hammer."

Hammer Dressing.—See "Dressing."

y.—A form of cant-hook with a spike in the end of the handle next to the hook; used by timber men.

Tie.—See "Tie."

—A footing for a tower post. A bridge shoe, *q.v.*

Block.—Same as "Base Casting." See "Casting."

Cap.—See "Cap."

Pier.—See "Pier."

Pile.—See "Pile."

Strut.—See "Strut."

y.—That part of a bridge floor set aside for pedestrians. A footwalk.

[illegible]

[illegible] with the [illegible]

[illegible] to the ground with [illegible]

Pegram Truss.—See "Truss."

Pein Hammer.—Same as "Peen [illegible]

Pendulum.—Anything that hangs [illegible]

Pendulum Pile Driver.—See "Pile [illegible]

Pendulum Saw.—See "Saw."

Pene.—Same as "Peen," q.v.

Pene Hammer.—Same as "Peen [illegible]

Penetration.—A term used in [illegible] pile has been driven in the soil. Also [illegible] and asphaltic fluxes to determine [illegible] centimeter to which a standard needle [illegible]

Pennsylvania Truss.—See "Truss."

Per Cent of Heart.—See "Heart."

Perch.—A stone mason's unit of [illegible] 24¾ cubic feet, depending upon local [illegible] couraged as far as possible, as its [illegible]

Percolation.—The process of straining or [illegible] or other fluid through the pores of a solid.

Percussion.—The act of striking one body [illegible]

Centre of Percussion.—That point of a [illegible] thereon no reaction will be developed at the [illegible] identical with the centre of oscillation and is [illegible] point of suspension that if the whole mass of [illegible] the time of oscillation would remain unchanged.

Percussion Cap.—See "Cap."

Percussion Drill.—See "Drill."

Percussion Fuse.—See "Fuse."

Perimeter.—The outer boundary of a figure.

Periodic Curve.—See "Curve."

Periodic Deposit.—A payment made at regular [illegible]

Period of Vibration.—See "Vibration."

Periphery.—The boundary line of a closed figure, [illegible]

Periphery Lines.—See "Line."

Permanent Set.—Same as "Hard Set." See "Set."

Permeability.—The quality or condition of being [illegible] by liquids or gases.

Perspective.—The art of representing solid objects on a [illegible] are viewed, the eye is affected in the same manner [illegible] objects themselves from a given point.

Centre of Perspective.—The point which is collinear [illegible] ing points of two figures in perspective.

Perspective Drawing.—See "Drawing."

Pestle.—A rounded, pear-shaped tool with a handle, used for the grinding and pulverizing of materials in a mortar.

Pet Cock.—See "Cock."

Petit Truss.—See "Truss."

Philadelphia Rod.—See "Rod."

Phœnix Column.—See "Column."

Phosphor-bronze.—An alloy of copper and tin containing from one-half to one per cent of phosphorus. It makes hard castings and has an ultimate tensile strength varying from 50,000 to 100,000 pounds per square inch.

Phosphorus.—A chemical element having a strong affinity for oxygen, encountered as an impurity in iron ores. Its presence causes cold shortness in steel.

Pick.—A hand-tool for excavating hard soils, consisting of a heavy curved bar, having one end pointed and the other wedge-shaped, and having a hole in the enlarged central portion for the insertion of a handle.

Pick Axe.—See "Axe."

Picked Dressing.—A type of stone dressing. See "Dressing."

Pickling.—The treatment of iron or steel with dilute acids for the purpose of obtaining a clean surface by removing the scale (oxide).

Pick-pole.—A small pike pole without the hook.

Pick-up Bar.—See "Bar."

Picture Drawing.—See "Drawing."

Pier.—A structure, usually composed of masonry, which is used to transmit the loads from a bridge superstructure to the foundation.

Anchor Pier.—A pier used in cantilever bridges to resist the uplift at the end of the anchor arm.

Battered Pier.—A pier having its sides slightly inclined to the vertical, giving a larger section at the base than at the top.

Brick Pier.—Any pier made of bricks.

Buried Pier.—A small secondary pier built a short distance from the main shore pier and carrying the end of an approach span. It takes the place of an abutment and is more economical, as it has no wing-walls and does not have to resist the lateral pressure of the earth, because the embankment spills around it on all sides.

Concrete Pier.—A pier made of concrete.

Cylinder Pier.—A pier made of a cylindrical steel shell filled with concrete.

Dumb-bell Pier.—A pier composed of two cylindrical piers connected by a solid web.

Floating Pier.—A term applied to a pier sunk to a great depth in a soft, yielding, or semi-fluid soil and depending for stability on the principle of flotation.

Masonry Pier.—A pier constructed of stone masonry.

Pedestal Pier.—A combination of two pedestals on a common base, but having separate tops.

Pile Pier.—A pier formed by driving a cluster of piles and capping them with heavy timbers in the form of a grillage to carry the shoes of the span.

Pivot Pier.—The pier supporting a swing span and upon which it turns.

Pneumatic Pier.—A pier sunk by the pneumatic process.

Rest Pier.—A pier which supports one of the ends of a draw span.

Submerged Pier.—A pier entirely below the water line.

Timber Pier.—A pier constructed of timbers, usually in conjunction with piles.

Piercing.—Producing a hole in a body by forcing a pointed instrument through it, the displaced material being forced into the body. Distinct from punching.

Pier Footing.—See "Footing."

Pierre-perdue.—Lost stone. Rough stones thrown into the water and left to find their own slope. Used for pier and wharf protection.

[illegible]

[illegible] Pig.—Pig iron used [illegible]
content is limited to one [illegible]

Bessemer Pig.—Pig iron used [illegible]
in which the silicon content [illegible]
not over one-tenth of one per [illegible]

Cinder Pig.—A pig iron made [illegible]

Forge Pig.—An inferior grade of [illegible]
work.

Foundry Pig.—Pig iron used in the [illegible]

Malleable Pig.—Pig iron used for [illegible]

Pig Iron.—Same as "Pig," *q.v.*

Pigment.—The fine, solid particles [illegible]
insoluble in the vehicle.

Pig-washing.—A process of refining [illegible]
in which the molten pig iron is [illegible]
is mixed with oxides of manganese) [illegible]

Pike-pole.—A long, slender hand-pole [illegible]
for handling timber.

Pilaster.—A thin, flat projection from the [illegible]
for ornamental purposes.

Pile.—A long, heavy post or pole of [illegible]
to compact the soil, to shut out water, [illegible]
zontal force.

Anchor Pile.—A pile used for the [illegible]

Batter Pile or Battered Pile.—A pile driven [illegible]

Bearing Pile.—Any pile carrying a vertical [illegible]

Built Pile.—A pile made up of several parts. [illegible]

Cement Pile.—Same as "Concrete Pile," *q.v.*

Charred Pile.—A wooden pile having its lower [illegible]

Chenoweth Pile.—A rolled concrete pile designed [illegible]

Club-footed Pile.—Same as "Pedestal Pile," *q.v.*

Closing Pile.—The last pile driven for closing a [illegible]

Columnar Pile.—A pile in which the bearing [illegible]
hard stratum, depends chiefly on its action as a [illegible]

Concrete Pile.—A pile made of concrete.

Corrugated Pile.—A precast, tapered, concrete pile [illegible]
ning lengthwise, having reinforcing rods, and a [illegible]

Cushing Pile.—A square timber pile driven in a group [illegible]
tically in contact. This method of pile foundation [illegible]

Disk Pile.—A steel pile with a disk at the bottom [illegible]
It is used in soft sandy soils and requires the [illegible]

Falsework Pile.—A pile driven temporarily as a [illegible]
the erection of a span.

Fender Pile.—A pile which is driven at wharfs, or [illegible]
tures or other important works, to protect them [illegible]

Filling Pile.—A form of concrete pile made by first [illegible]
with a mandrel and, after withdrawing it, filling [illegible]

Foundation Pile.—A pile used permanently in the [illegible]

Gauge Pile.—Ordinary piles, driven at intervals of [illegible]
attached wales or runners against which are driven [illegible]

Gilbreth Pile.—A corrugated reinforced concrete pile [illegible]

Pile.—A pile driven near a caisson to act as a guide during sinking.

Pile.—A shell driven into the ground to receive concrete.

Pile.—Any pile that has been sunk by means of a jet.

ile.—The principal pile in a group of piles.

Pile.—A pile having four or more long longitudinal timbers bolted to the s for the purpose of increasing the area exposed to skin friction, and thereby ining an increased bearing capacity.

ng Pile.—A pile at the head of a row of piles.

r Pile.—Same as "Pedestal Pile," *q.v.*

ing Piles.—Piles used for fastening boats and barges.

stal Pile.—A patented pile formed by driving a steel shell into the ground to e required depth, putting in small quantities of concrete, and hammering them wn so as to force the concrete into the earth beyond the point of the shell, thus larging the end and greatly increasing the bearing area. The shell is afterward ithdrawn gradually, as the hole that it made is filled with concrete. If the shell re left in, the method would be far more satisfactory; as the shaft of the pile liable to be seriously imperfect. Sometimes dubbed a club-footed pile.

tration of Pile.—Same as "Penetration."

k Pile.—A pile built of planks.

b Pile.—A pile driven vertically, usually one of the inside piles of a bent.

matic Pile.—A small diameter steel cylinder sunk by the pneumatic process.

ast Pile or Premoulded Pile.—A form of concrete pile made in a mould and lowed to harden or season before being driven.

mond Pile.—A form of filling pile in which a steel shell is driven into the ground and allowed to remain, at the time of withdrawing the mandrel, so as to form a ning for the hole into which the concrete is poured.

fusal of Pile.—That condition in pile driving when further driving fails to increase the penetration.

lled Pile.—A type of concrete pile in which concrete is rolled up in a wire mesh, to which longitudinal reinforcing rods are attached. The mesh takes the form of a spiral during the process, which is continued until the desired size and shape are secured.

ound Pile.—A pile having a round cross-section.

d Pile.—A pile made by forming a hole in the ground and filling the same with nd thoroughly tamped.

ew Pile.—A steel pile similar to a disk pile but having a portion of a helicoid at s point so as to enable the pile to be screwed into place.

Pile.—A form of piling used to shut out water, generally made of several lanks spiked or bolted together, and arranged to secure a tongued and grooved ffect when driven close together. Steel shapes are also employed for this purpose.

lex Pile.—A type of filling pile made by driving a steel shell, having a steel int, into the ground and filling same with concrete while the shell is being withwn.

d Pile.—A pile composed of two or more sticks joined with scabs.

Pile.—Same as "Batter Pile," *q.v.*

e Hewed Pile.—A timber pile trimmed with an adze into an approximately e section.

ing Pile.—A pile which stands without bracing.

Pile.—A pile connected or anchored by land ties with the main piles in the pile work.

—Piles made of rolled steel rods or shapes.

—A pile in place loaded with a known weight in order to test the bearing of the soil.

[illegible] Pile Driver.—A [illegible]

[illegible] and raising the [illegible]

[illegible] for the man to [illegible]

[illegible]

[illegible] beam and [illegible]

[illegible] Pile Driver.—A pile [illegible]

[illegible] Pile Driver.—A [illegible]

the top of the pile and, by the [illegible]

[illegible] Pile Driver.—A small pile [illegible]

Horse Pile Driver.—A driver in [illegible]

Monkey Pile Driver.—Same as "[illegible]

Nipper Pile Driver.—A pile driver in which [illegible] during lifting. It is tripped at the top [illegible]

Pendulum Pile Driver.—A driver in which [illegible] pendulum so that a pile can be driven [illegible]

Track Pile Driver.—A driver mounted [illegible] along the track.

Pile Driver Hammer.—See "Hammer."

Pile Ferrule.—Same as "Pile Band," *q.v.*

Pile Follower.—Same as "Follower," *q.v.*

Pile Foundation.—See "Foundation."

Pile Hammer.—See "Hammer."

Pile Head.—See "Head."

Pile Line.—See "Line."

Pile Pier.—See "Pier."

Pile Planks.—See "Plank."

Pile Ring.—Same as "Pile Band," *q.v.*

Pile Ring Puller.—A device for pulling a pile ring [illegible] been driven. Usually a cant hook is employed [illegible]

Pile Shoe.—See "Shoe."

Pile Splice.—See "Splice."

Pile Trestle.—See "Trestle."

Pile Work.—See "Work."

Piling.—A general term for a number of piles taken [illegible]

Sheet Piling.—A general term for a number of [illegible] "Pile."

Pillar.—A post or column.

Pillaring.—The act of supplying with pillars. A system [illegible]

Pillow or Pillow Block.—See "Block."

Pillow Joint.—Same as "Ball and Socket Joint." See [illegible]

Pilot Nut.—See "Nut."

Pilot Punch.—See "Punch."

Pin.—A round bar of steel used for connecting members [illegible] bar which fills a hole. A pivot.

Centre Pin.—The pin on which the needle of a compass [illegible]

Chord Pin.—Any pin on, or very near, the centre line [illegible]

Pin.—A pin used to connect a clevis with a plate.

Pin.—A split steel key or pin used to fasten large pins so that they cannot ove endwise. Also used to denote the large pin holding the cotter.

ling Pin.—A pin that couples links in machinery, chains, etc.

k Pin.—A pin connecting the ends of a double crank or the projection from the d of a single crank.

-head Pin.—A pin that fits in a cross-head and furnishes an attachment for the necting rod.

Pin.—A hand tool made of tempered steel with tapering ends and of a size that ll permit its being pushed through a rivet hole. Used to draw together the mponent parts of a member or adjacent members.

Pin.—A truss pin at the end of a span connecting the truss to the shoe.

geon Pin.—Same as "Gudgeon," *q.v.*

le Pin.—One of the pins which keep a hub and felloe central with the axis of e machine to which they pertain.

ge Pin.—A pin which fastens together the parts of a hinge or which connects members having a slight rotating movement about each other.

h Pin.—A pin, near the end of an axle, used to hold on a wheel.

t Pin.—A vertical pin at the top of the mast of a derrick.

Pin.—Same as "Dowel," *q.v.*

e Pin.—The pin in a shoe which receives the load from a span or a column.

ss Pin.—A pin used at the panel point of a truss to connect the several intersecting members.

earing.—See "Bearing."

olt.—A bridge pin having a head and a nut.

Bar.—See "Bar."

onnected.—A term applied to the method of joining the members of a truss by pins instead of using riveted connections.

onnected Truss.—See "Truss."

Drill.—See "Drill."

—A species of the conifers, or evergreen trees.

oblolly Pine.—A variety of pine tree of large size. It has a wider ringed, coarser, lighter, and softer wood with a larger area of sap wood than the long-leaf yellow pine. Its needle-like leaf is of short length.

ng-leaf Yellow Pine.—A variety of pine tree of large size, having a hard, dense, strong wood and a needle leaf of great length.

Norway Pine.—A variety of pine tree of large size. The wood is largely sap-wood and not durable. Grows in small scattering groves.

ort-leaf Yellow Pine.—A variety of pine tree resembling the loblolly pine and having a wood approaching that of the Norway pine. Its needle leaf is shorter than that of the loblolly or Norway pine.

hite Pine.—A variety of pine tree of small size and soft wood. It has a short needle-like leaf.

nd or Pin-ended.—The condition of having a pin connection at the end of a member.

ed Column.—See "Column."

Filler.—See "Filler."

e.—A hole in a member through which the pin passes and connects with other members.

e Cutter.—See "Cutter."

—Any toothed gear of small size as compared with the gear which it engages.

Pinion.—A small lantern wheel. See "Wheel."

[illegible]

Pinion Shaft.—See "Shaft."

Pin Joint.—See "Joint."

Pin Knot.—See "Knot."

Pin Maul.—See "Maul."

Pin Metal.—See "Metal."

Pinner.—In masonry construction, a [illegible] process involved (a most [illegible] pinning." It causes the pressure on [illegible] of being equally distributed over it, [illegible]

Pin Nut.—See "Nut."

Pinny.—An English term for a metal [illegible] than the rest.

Pin Pilot.—Same as "Pilot Nut." See "Nut." [illegible]

Pin Plate.—See "Plate."

Pipe (in metal).—A defect in an ingot due to [illegible] and the resulting contraction leaving a [illegible]

Pipe.—A tube, a conduit, a hollow metallic [illegible]

Blast Pipe.—The exhaust pipe of a steam [illegible]

Blow Pipe.—A pipe through which material is [illegible] tube through which air is forced so as to produce [illegible]

Cast-iron Pipe.—Pipe made of cast iron.

Drip Pipe.—A small pipe used to convey away [illegible] steam pipe.

Jet Pipe.—A pipe used in jetting, having a nozzle [illegible] supply hose at the upper.

Joint Pipe.—A short section of gas or steam pipe, [illegible]

Gas Pipe.—Small wrought iron pipe.

Lead Pipe.—Pipe made by squeezing lead through [illegible]

Loricated Pipe.—A pipe, having an inside coating [illegible] electric wires.

Spiral-riveted Pipe.—A pipe made of long, narrow [illegible] form and riveted together.

Suction Pipe.—The pipe running from a pump to the [illegible]

Weeping Pipe.—A pipe embedded in the masonry to [illegible] from the top or back of a pier or abutment.

Wrought-iron Pipe.—Pipe made from rolled iron [illegible] Small sizes are butt-welded, while larger sizes are [illegible]

Pipe Clamp.—See "Clamp."

Pipe Coupling.—See "Coupling."

Pipe Cutter.—See "Cutter."

Pipe Die.—See "Die."

Pipe Joint.—See "Joint."

Pipe Line.—See "Line."

Pipe Rail.—See "Rail."

Pipe Tougs.—See "Tongs."

Pipe Union.—See "Union."

Pipe Vise.—See "Vise."

Pipe Wrench.—See "Wrench."

Piping.—A general term used to denote a group or system of pipes taken collectively. A defect in rolled steel due to cavities that were formed as the ingot cooled. See "Pipe."

Piston.—A movable disk-like piece fitted to fill the cross-section of a pipe or cylinder and capable of a backward and forward motion.

Air Piston.—The piston that works in the air cylinder of an air compressor.

Double-acting Piston.—A piston that is subjected to fluid pressure on each side alternately.

Single-acting Piston.—A piston which is subjected to periodic pressure on one side only.

Piston-head.—Same as "Piston," *q.v.*

Piston Rod.—See "Rod."

Piston Valve.—See "Valve."

Pit.—The effect of steam, water, or gas on metal causing small holes to appear on the surface. A hole in the ground.

Foundation Pit.—An excavation in which a foundation is placed.

Lock Pit.—A pit in which the locking machinery is installed.

Working Pit.—The excavation made for a foundation.

Pitch.—The distance measured along the pitch line from center to center of teeth on a cogwheel. The slope of a roof. The distance from center to center of rivets. The distance between the adjacent threads of a screw. The degree of descent of a declivity. A thick, tenacious, black or dark-brown substance obtained by boiling down tar. The resinous sap that exudes from pines. Bitumen or asphaltum, especially when unrefined. To smear, cover, or treat with pitch.

Chord Pitch.—The distance between centres of teeth, measured on the chord of the pitch circle of a gear.

Circular Pitch.—The distance between centres of teeth, measured on the pitch circle of a gear. Also called the pitch of the tooth.

Diametral Pitch.—In English practice, the ratio of the diameter of the pitch line to the number of teeth which is equivalent to the ratio of the circular pitch to π. In American practice, the ratio of the number of teeth to the diameter of the pitch circle in inches, which is equivalent to the ratio of π to the circular pitch.

Pitch Circle.—That circle of a gear, passing through the teeth, having a diameter which measures the velocity ratio of the gear in respect to another which engages it.

Pitched Dressing, or **Pitched-face Dressing.**—See "Dressing."

Pitching Chisel.—See "Chisel."

Pitching Tool.—A hand tool used by masons for cutting the arris on a stone.

Pitch Line.—See "Line."

Pitch of Rivet.—See "Rivet."

Pitch Streak.—A well-defined accumulation of pitch at one point in a piece of timber.

Pitch Wheel.—See "Wheel."

Pitman.—A rod which connects a rotating with a reciprocating part in an engine or other machine.

Pit Planer.—See "Planer."

Pit Saw.—See "Saw."

Pivot.—A pin or shaft on which any object turns.

Pivoted.—Arranged to work on a pivot.

Pivot Gearing.—See "Gearing."

Pivot Joint.—See "Joint."

Pivot Pier.—See "Pier."

Pivot Span.—A span in a bridge that revolves; called also "draw-span" and "swing-span."

Plain Dressing.—See "Dressing."

Plain Hammer.—Same as an "Engineer's Hammer." See "Hammer."

Plain Rod.—See "Rod."

[illegible]—See "Plank."

[illegible]—See "Joist."

[illegible]

Plane of Symmetry.—See "Symmetry

Planer.—A machine tool for

Pit Planer.—A type of planer

Stone Planer.—A machine for

Plane Table.—A surveyor's instrument

tripod, and having on its upper

sight vanes or a telescope.

Planimeter.—An instrument for

its periphery and noting the

Polar Planimeter.—A planimeter having

while the other end carries the

Rolling Planimeter.—A planimeter in which

mounted on rollers.

Planish.—To polish metals by rubbing with a

Plank.—A piece of lumber thicker than a

inches in thickness and from six inches

Felloe Plank, or Felly Plank.—A guard rail

felloe of a wheel and thus prevent the

bridges, a felloe plank is often placed

vehicles passing from one side to the other.

Floor Plank.—A plank used in the flooring

Gang Plank.—A short, temporary plank used

or other vessel to a wharf.

Hub Plank.—See "Hub."

Moulding Planks.—Planks on which ornamental

condition.

Pile Planks.—Planks driven like piles.

Plank Pile.—See "Pile."

Plant.—The fixtures, machinery, tools, apparatus, etc.

facturing or erecting business.

Plate.—A flat piece of metal or wood.

Anchor Plate.—A square or rectangular plate, or

bolt.

Base Plate.—The foundation plate of metal on which

the end of a bridge rests. This plate is usually set

Batten Plate.—A stayed plate at the ends of a

termed tie plate or stay plate.

Beam-hanger Plate.—The plate beneath the ends of a

nuts to press against.

Bearing Plate.—A plate which receives the bearing

on another plate.

[illegible]—A plate set in the top of the masonry to carry the load from [illegible]

[illegible] **Plate.**—Iron or steel rolled into flat plates from one-quarter to [illegible] used in making tanks, boilers, vessels, etc. Sometimes called [illegible]

Buckle Plates.—Flat steel plates which are dished at regular intervals. Used for floor plates.

Cap Plate.—The top plate on a steel column or post. It generally supports a load.

Checkered Plate.—A cast steel or iron plate having square, flat projections suggestive of a checkerboard. Its function is to give a foothold for horses.

Compound Web Plate.—See "Web Plate."

Connecting Plate.—A plate used to connect two or more members of a truss.

Corrugated Plate.—A steel plate bent into a series of parallel furrows and [illegible]

Cover Plate.—A plate fastened on the flanges of a girder to give additional [illegible] section thereto; a top or bottom plate of a chord member.

Diaphragm Plate.—A stiffening plate used in the interior of a column to give it additional strength and rigidity.

Draw Plate.—A plate having tapered holes through which wires are drawn.

Extension Plate.—See "Jaw Plate."

Filler Plate.—A plate used to fill open spaces under members or parts thereof.

Fish Plate.—Same as "Splice Bar." See "Bar."

Flange Plate.—Same as "Cover Plate," *q.v.*

Flitch Plate.—A plate in a compound wood and steel beam.

Gusset Plate.—A large connecting plate used at panel points to join the chord and the web members.

Hanger Plate.—A gusset plate connecting the hip-vertical to either the top or the bottom chord.

Hinged Plate.—A plate containing a pinhole for hinging the end of a member.

Hitch Plate.—A plate having a hole or a ring attached for tying lines thereto.

Jaw Plate.—The unsupported portion of the end of a compression member remaining after the outstanding legs of flange angles have been cut away, and its pin plates, which extend below the transverse diaphragm to allow the packing of other members on the same pin.

Masonry Plate.—A plate used under a bridge-shoe for the purpose of distributing the load on the masonry.

Name Plate.—A plate attached to a bridge showing the names of the designer, fabricator, and erector. Sometimes other names are added.

Pin Plate.—A plate riveted to the outside of the end of a member to give additional strength and greater bearing on the pin.

Reinforcing Plate.—An extra plate used to reinforce or strengthen a member.

Roller Plate.—A bed plate on which the rollers of the expansion end of a truss rest.

Scab Plate.—Same as "Scab," *q.v.*

Sheared Plate.—A plate sheared from another larger plate. Any plate the edges of which are sheared.

Shimming Plate.—A plate used as a shim for increasing the elevation of a bearing.

Shoe Plate.—The bottom plate of a shoe resting on the masonry.

Skimming Plate.—A cast iron plate used to separate from the molten metal the small amount of a slag which comes out of the furnace therewith.

Sole Plate.—A plate riveted to the bottom flange of a plate girder to bear on the masonry plate.

Splice Plate.—A plate used in splicing or joining two parts of a member.

Stay Plate.—Same as "Batten Plate," *q.v.*

Tie Plate.—Same as "Batten Plate," *q.v.* A plate used between a rail and a tie.

Tongue Plate.—A plate riveted on to the end of a member and projecting beyond it, in order to make a connection with another member.

[illegible]

[illegible] Plate.—A steel plate [illegible]
[illegible] beams and [illegible]

[illegible] Plate.—The plate [illegible]

[illegible] Plate.—The revolving [illegible]
versions.

Plate Gauge.—See "Gauge."

Plate Girder.—See "Girder."

Plate Washer.—See "Washer."

Play.—A looseness in a joint or in [illegible]
freedom of motion.

Plenum Process.—The pneumatic process [illegible]

Pliability.—The capacity of a body to [illegible]
stresses.

Pliers.—A hand tool for manipulating [illegible]

Plinth.—The square block at the base of a [illegible]

Plug.—A small block of any material used to [illegible]
steel used to drive between the feathers [illegible]
splitting or quarrying stone.

Plug-and-feather Method.—A method of [illegible]
a few inches apart, to a convenient depth [illegible]
then inserting steel feathers in each hole [illegible]
plug, between them. This causes an [illegible]
holes.

Plug Cock.—See "Cock."

Plugged.—Stopped up with a plug.

Plugged Rivet.—Same as "Calked Rivet." See [illegible]

Plumb.—Vertical.

Plumbago.—Same as "Graphite," *q.v.*

Plumb-bob.—A conical piece of metal attached at [illegible]
place an object in a vertical position or directly [illegible]

Plumb Line.—See "Line."

Plumb Pile.—See "Pile."

Plumb Post.—See "Post."

Plummer Block.—Samé as a "Pillow Block." See [illegible]

Plummet.—A ball of metal attached to the end of a [illegible]
of water.

Plunger.—The piston in a pump.

Ply.—A term used to designate the number of layers in a [illegible]
a four-ply belt.

Pneumatic.—Pertaining to air, processes using air, or [illegible]
air.

Pneumatic Caisson.—See "Caisson."

Pneumatic Car.—See "Car."

Pneumatic-clippers.—Shears or clippers operated by com[illegible]

Pneumatic Cutter.—See "Cutter."

Pneumatic-cylinder.—The cylinder of a pier sunk by [illegible]
cylinder in an air-compressor in which the air is com[illegible]

Pneumatic Drill.—See "Drill."

Pneumatic Elevator.—See "Elevator."

Excavator.—See "Excavator."

Hammer.—See "Hammer."

tic Hoist.—Same as "Air Hoist." See "Hoist."

tic Pier.—See "Pier."

atic Pile.—See "Pile."

atic Process.—The process of sinking caissons by pumping air into the working chamber, in order to exclude the water, and thereby affording a dry space in which excavation may be carried on.

matic Riveter.—Same as "Air Riveter." See "Riveter."

matic Riveting Gun.—See "Gun."

et.—A recess. A hole in rolled metal, as a cinder pocket.

nder Pocket.—A pocket made in rolled steel by rolling cinders into the [illegible] These may either remain or drop out of the rolled product, leaving [illegible] or pockets.

ansion Pocket.—A bracket or pocket carrying a sliding end of a girder [illegible]

h Freezing Process.—A method of freezing quicksand, soft mud, or silt [illegible]ing tubes down into it and circulating a freezing mixture through them u[illegible] surrounding material is converted into a frozen mass like a wall.. Excavation [illegible] then be carried on inside of the wall.

ch-Sooysmith Process.—Same as the "Pœtsch Freezing Process," *q.v.* This term is used to denote the American right, held by Mr. Charles Sooysmith, to use the process.

(gear teeth).—See "Tooth."

(stone dressing).—A short steel bar with one tapering end sharpened to a point, used by masons for dressing stone.

ed Dressing.—See "Dressing."

of Curve.—On railroad work, the point at which a tangent ends and a curve begins, called P. C.

t of Intersection.—The point where two tangents cross. Used in railroad work and called P. I.

t of Tangent.—In railroad work, the point where a curve ends and a tangent commences, called P. T.

t Switch.—See "Switch."

on's Ratio.—The ratio of the lateral deformation to the longitudinal deformation under longitudinal external forces.

r.—Relating to a pole or axis.

r Axis.—See "Axis."

r Coordinates.—See "Coordinates."

r Distance.—Same as "Pole Distance," *q.v.*

-equation.—An equation connecting polar coordinates.

r Moment of Inertia.—See "Inertia."

r Planimeter.—See "Planimeter."

.—Any long, round, slender piece of wood. Either of the extremities of the axis of a sphere. A point about which an object rotates. A point from which lines radiate.

Leveling Pole.—Same as "Leveling Rod." See "Rod."

Range Pole.—A slender, painted pole having red and white bands alternating to give distinctness. Used by surveyors in sighting and running lines.

e Axe.—See "Axe."

-distance.—The perpendicular distance, in a force diagram, from the pole to the load line.

-plate.—A longitudinal timber resting on the ends of tie-beams of roofs; used for supporting the feet of the common or jack rafters.

.—See "Tie."

[illegible]

the magnitude and direction of the

[illegible] Polygon, or String Polygon

[illegible] Top Chord.—See "Chord."

Pontoon.—A boat or light boat

A floating bridge.

Pontoon Bridge.—See "Bridge."

Pony Truss.—See "Truss."

Porosity.—The condition of perviousness

Port.—The narrow slot in the ends of a cy
the left-hand side looking forward—
for vessels.

Portal.—The space between the batter
term is applied to the portal bracing.

Skew Portal.—A portal on a skew span.

Portal Bracing.—See "Bracing."

Portal Rod.—See "Rod."

Portal Strut.—See "Strut."

Portland Cement.—See "Cement."

Portland Cement Concrete.—See "Concrete."

Portland Cement Grout.—See "Grout."

Positive Moment.—See "Moment."

Positive Print.—See "Print."

Positive Reaction.—See "Reaction."

Positive Rotation.—See "Rotation."

Positive Shear.—See "Shear."

Post.—A vertical, or nearly vertical, compression

Batter Post.—Same as "Batter Brace." See "Brace."

Beam-trussing Posts.—The short, perpendicular posts

Centre Post.—An intermediate post on the
bent.

Collision Post.—An auxiliary post placed near the
shock of a derailed car or engine and prevent it from

End Post.—The post at the end of a truss.

Fixed Post.—A post having fixed ends.

Handrail Post.—A post supporting the handrail and
member of a handrailing.

Hinged Post.—A post having one or both ends
the structure.

Inclined End Post.—An inclined compression member
called "Batter Post" and "Batter Brace."

Intermediate Post.—A post between the two outside

Post.

Joggle Post.—A post built of two or more pieces of timber held together with dowels or joggles. A post having shoulders to receive the feet of struts; a king post.

King Post.—The middle post standing at the apex of a King Post Truss. See "Truss." Also called "Joggle Post," *q.v.*

Newel Post.—The principal post at the angles or at the foot of a stairway.

Plumb Post.—A vertical post, usually applied to timber construction.

Queen Post.—The vertical post in a "Queen Post Truss." See "Truss."

Snubbing Post.—A post used for snubbing or attaching loosely a line to check the motion of a boat.

Sub Post.—A secondary post used in a subdivided panel.

Tower Post.—A member of a tower which carries load directly to the pedestal. A tower column.

Post Extension.—Same as "Jaw Plate," *q.v.*

Post-hole Auger.—See "Auger."

Post-Oak.—A variety of white oak.

Post Reamer.—Same as "Post-hole Auger," *q.v.*

Post Truss.—See "Truss."

Potential Energy.—See "Energy."

Pot Metal.—See "Metal."

Pounce.—Powdered talc or chalk used for rubbing on tracing cloth to remove the slightly greasy surface so that the ink will adhere better.

Pound-foot.—A unit of moment, equal to that produced by a force of one pound acting with a lever arm of one foot.

Powder.—Same as "Gun Powder," *q.v.* An explosive used for blasting. Any very finely pulverized substance. To reduce to powder. To pulverize. To sprinkle with powder.

Power.—The rate of doing work. Often loosely used for force, strength, or resistance.

Horsepower.—A unit of power. See "Horsepower." Also a machine by which the power of a horse can be made available for doing useful work.

Water-power.—Power developed from moving water; also applied to any plant used for generating power from moving water.

Power Capstan.—See "Capstan."

Power Crane.—Same as "Column Crane," *q.v.*

Power Hammer.—See "Hammer."

Power House.—The building containing the machines and equipment used in generating power.

Pozzuolana Cement.—See "Cement."

Prairie-type Locomotive.—See "Locomotive."

Pratt Truss.—See "Truss."

Pre-cast Pile or **Pre-moulded Pile.**—See "Pile."

Precipitation.—A general term for the several kinds of moisture from the atmosphere deposited on the earth's surface, such as dew, mist, rain, frost, snow, sleet, hail, etc. The process by which a substance in solution, after another substance has been added, reacts upon the latter, forming a new insoluble compound called precipitate.

Precise Level.—See "Level."

Present Worth.—The present worth of a sum of money due a number of years hence is that principal which at compound interest will produce the desired amount at the end of the given time. The present worth of a sinking fund is equal to the present worth of the amount of the fund, and is the sum of the present worths of the deposits.

Press.—A machine for exerting pressure upon an object.

Buckle-plate Press.—A machine for pressing sheet steel into buckle-plates.

Bull Press.—Same as "Gag Press," *q.v.*

[illegible]

[illegible]

[illegible]

in a frame. A small [illegible]
move slowly, but with great [illegible]

[illegible] Press.—A machine used [illegible]
out the slag. The action thereof [illegible]

Pressed Brick.—See "Brick."

Pressed Threads.—See "Threads."

Pressure.—The effect of pressing; the [illegible]

Air Pressure.—The pressure exerted by [illegible]
pressed and confined in a reservoir.

Axis of Pressure.—A line passing through [illegible]
successive sections of a body.

Bearing Pressure.—The pressure on a bearing [illegible]

Centre of Pressure.—The point at which the [illegible]
acts.

Earth Pressure.—The lateral pressure exerted [illegible]
by a retaining wall or an abutment.

Teeth Pressure.—The pressure exerted by [illegible]

Water Pressure.—The pressure exerted by a [illegible]

Wind Pressure.—The pressure on a surface [illegible]

Pressure Gauge.—See "Gauge."

Pricker.—A needle point mounted in a handle, [illegible]
position of a point on one plan to another by [illegible]
pricking through.

Prick Punch.—See "Punch."

Primary Member.—See "Member."

Primary Stress.—See "Stress."

Primary Truss.—See "Truss."

Prime.—To pour water down a pump in order to [illegible]

Primer.—The first coat of paint on a structure; an [illegible]

Priming Coat.—The first coat of paint on a structure, [illegible]

Principal.—A sum of money upon which interest is paid [illegible]

Principle of Least Work.—See "Least-work."

Print.—An impression; a copy.

Blue-print.—A copy made on blue-print paper from a [illegible]

Negative Print.—An intermediate print from which [illegible]
made.

Positive Print.—A blue line print on white background [illegible]
without a negative.

Van Dyke Print.—A print made on Van Dyke brown [illegible]

Printing Frame.—See "Frame."

Printing Machine.—An apparatus for making blue-prints [illegible]
light.

Prismoid.—A solid having two parallel plane bases with [illegible]
lines.

Prismoidal Formula.—A formula for finding the exact vo[illegible]

Let A_1 = area of one base,

A_2 = area of other base,

M = area of middle section parallel to bases, [illegible]

Let l = distance between bases,
V = volume,

$$\text{then } V = \frac{l}{6}(A_1 + A_2 + 4M)$$

Prison Dressing.—See "Dressing."

Profile.—The outline of a vertical section through a country or line of work, showing actual or projected elevations and hollows, generally with the vertical scale much greater than the horizontal.

Profile Book.—A surveyor's note book. A case in which a continuous strip of profile paper is carried.

Profile Paper.—See "Paper."

Progression.—A series of numbers bearing a definite sequential relation to each other.

Arithmetical Progression.—A progression in which any term, other than the first, is derived from the preceding term by adding a fixed quantity.

Geometrical Progression.—A progression in which any term, other than the first, is derived from the preceding term by multiplying the latter by a fixed quantity.

Projection.—The act, or its result, of constructing rays or lines through every point of a figure, according to some system or law, and extending or projecting them to some plane upon which the figure or object is to be represented.

Isometric Projection.—A mode of geometrical drawing in which three planes are projected at equal angles upon a single plane, and all the measurements are upon the same scale; used at times to show machinery, buildings, etc.

Orthographic Projection.—That system of projection in which the rays are parallel. This is the system which is most largely used in engineering work.

Prony Friction Brake.—See "Brake."

Proof Load.—See "Load."

Proof Strength.—See "Strength."

Prop.—A temporary support or extraneous brace.

Pry.—A lever. To raise with a lever.

Puddle.—To compact and work into place, as to puddle concrete. To convert cast iron into wrought iron by melting and stirring in a reverberatory furnace. A mixture of sticky clay moistened with water, used to stop leaks in cofferdams, etc. To place such a mixture.

Puddle Ball.—A lump of red-hot, plastic iron taken from the puddling furnace for hammering or rolling.

Puddle Bar.—Same as "Muck Bar." See "Bar."

Puddle Cinder.—See "Cinder."

Puddle Dyke.—See "Dyke."

Puddler.—A workman who is employed in the process of converting pig iron into wrought iron. The attendant at a puddling furnace.

Puddle Rolls.—See "Rolls."

Puddler's Candle.—One of the jets of flame which spring from molten iron while the carbon is being removed in a puddling furnace.

Puddle Steel.—See "Steel."

Puddle-train.—A set of rolls for rolling puddle balls into muck bar.

Puddle Wall.—See "Wall."

Puddling.—The act of making a puddle. See "Puddle."

Dry Puddling.—The old process of puddling iron in which very little, if any of the phosphorus was removed, while the sand lining of the furnace combined with the iron which was oxidized, thus causing a heavy loss.

Wet Puddling.—The present process of puddling, in which the furnace is first charged with fluxing cinder or "hammer slag" (oxide of iron) and then with gray iron. Afterward the charge is heated so that the iron and the flux form a pasty mass, which is then stirred with puddling bars.

[illegible]

and ropes usually [illegible]

Cone Pulley.—Same as [illegible]

Crowned Pulley.—A pulley [illegible]

Crowning Pulley.—A pulley in [illegible] the belt on better.

Dead Pulley.—Same as "Loose Pulley [illegible]

Differential Pulley.—A system of pulleys [illegible] upper grooved pulleys, of different [illegible] weight to be lifted is attached. [illegible] upon the larger pulley, it unwinds [illegible] moves through a space equal to half [illegible] wound up and that unwound.

Double-speed Pulley.—A combination of two [illegible] one fast-driven pulley, whereby two [illegible] with pulleys of the same diameter by [illegible] one of the loose pulleys.

Driven Pulley.—The pulley which receives the [illegible]

Driving Pulley.—The pulley transmitting motion [illegible]

Fast Pulley.—A pulley which is fastened to its [illegible]

Flat-rope Pulley.—A pulley having a flat face, [illegible] which passes a flat rope.

Frame Pulley.—A type of pulley-block having [illegible] or grooved pulleys turn.

Friction Pulley.—A pulley which transmits its motion [illegible] rolling surfaces instead of by teeth.

Guide Pulley.—A pulley employed to alter the [illegible]

Idle Pulley.—Same as "Loose Pulley," *q.v.*

Jockey Pulley.—A small wheel running against the [illegible] the rope or chain in its groove.

Loose Pulley.—A pulley which turns loosely on its [illegible]

Parting Pulley.—Same as "Split Pulley," *q.v.*

Sliding Pulley.—A pulley with a clutch mechanism [illegible]

Split Pulley.—A pulley made of two parts, held together [illegible] that it can be removed from its shaft without [illegible]

Stepped Pulley.—A pulley having a stepped face [illegible] thus permitting of a shifting of the belt and the [illegible]

Pulley Block.—See "Block."

Pulley-check.—An automatic device to prevent the rope [illegible] the pulley block.

Pulley Clutch.—See "Clutch."

Pulley Sheave.—See "Sheave."

[illegible] or Pulsometer Pump.—A pump in which the condensation of [illegible] chamber causes a partial vacuum therein, inducing the water to [illegible] pelled therefrom by an incoming fresh supply of steam.

[illegible]—To reduce to a powder.

[illegible]—A machine for moving liquids or gases by setting up a flow of same.

[illegible]ump.—A pump for condensing and forcing air through an aperture or pipe.

[illegible]t Pump.—A pump for raising liquids by means of buckets attached to a belt [illegible] chain and passing over an overhead shaft or a pulley or sprocket wheel.

[illegible]rifugal Pump.—A rotary pump in which a revolving fan creates a partial vacuum [illegible] its chamber, causing the water to rise until it comes in contact with the swiftly [illegible]oving vanes by which it is expelled through the discharge pipe.

[illegible]n Pump.—A pump employing an endless chain provided at intervals with buckets [illegible] with flat valves or disks working in a tube, used for raising water short distances. [illegible] is an uneconomic device.

[illegible]key Pump.—A feed pump for boilers.

[illegible]' Pump.—A pump employing a water jet to entrain air and thereby suck up [illegible]ud and wet sand into a chamber where it is caught by the jet and carried out [illegible]rough a discharge pipe.

[illegible]'s Foundation Pump.—A pump specially adapted for pumping out cofferdams [illegible] cribs.

[illegible] Water Pump.—Same as "Donkey Pump," *q.v.*

[illegible] Pump.—A pump worked by man power.

[illegible]ontal Pump.—A pump with its cylinders in a horizontal position.

[illegible]-head Pump.—A pump having its delivery pipe attached to the pump barrel by [illegible]oose-neck connection.

[illegible] Pump.—Any pump in which the fluid is impelled through the discharge pipe by [illegible] action of a jet of the same or another fluid.

[illegible]r Pump.—A portable, hand-lever pump, usually provided with an attachment for an air chamber and a nozzle to which a hose may be attached.

[illegible] Pump.—A pump having a cylinder with a suction valve at its lower end which is connected by a suction pipe to the water supply. The movable piston has an upward opening valve so that the water may pass through it on the downward stroke and lift by it when closed on the upper stroke.

[illegible]comotive Pump.—The feed pump which supplies water to a locomotive boiler.

[illegible] Pump.—A pump used for pumping mud out of an excavation, usually a cen[illegible]rifugal pump, although sometimes a jet pump, such as the Eads' pump is employed.

[illegible]someter Pump.—Same as "Pulsometer," *q.v.*

[illegible]tary Pump.—A pump that lifts water by the rotary motion of its parts.

[illegible]nd Pump.—A pump for raising sand, such as the Eads' pump.

[illegible]ction Pump.—A pump that raises water by creating a partial vacuum or suction.

[illegible]h.—A machine for forcing or shearing holes in metal. To make a hole with a punch.

[illegible]cking-out Punch or B. & O. Punch.—A hand tool used by erectors for backing out of the rivet-hole that portion of the rivet remaining after cutting off the head. Also called "B. and O. Punch."

[illegible]tre Punch.—A marking punch that makes a small indentation in steel so as to [illegible]cate the centre for a rivet-hole.

[illegible] Punch.—A machine that punches two or more holes at one operation.

[illegible]ple Punch.—Same as "Gang Punch," *q.v.*

[illegible] Punch.—A machine punch in which the cutting tool is provided with a small [illegible]tral plug which fits into a hole in the material and acts as a guide for punching [illegible] larger hole.

[illegible] Punch.—A hand tool for marking metal. A centre punch.

[illegible] Punch.—A punching machine that is operated by means of a ratchet wheel.

Punch.

Single Punch.—A punching machine that makes one hole at a time.

Spacing Punch.—A punch with an arm extending horizontally and having on the end of this arm a small tool, called a spotter, which engages a template working on a frame, to which is attached the sheet to be punched. When the frame is moved so that the spotter enters the hole in the template, the punch acts.

Square Punch.—A machine for punching square holes.

Sub-punch.—To punch a hole smaller than the rivet to be used, so that the injured metal may be removed by reaming out to size.

Template Punch.—Same as "Spacing Punch," *q.v.*

Punching Machine.—Same as "Punch," *q.v.*

Punish.—To subject material to very severe or abusive treatment.

Purchase.—A firm or advantageous hold used in prying a heavy object with a crowbar. A pivot, a fulcrum.

Purchase Blocks.—See "Block."

Pure.—Unadulterated.

Pure Stress.—See "Stress."

Purlin.—A piece of timber laid horizontally upon the principal rafters of a roof to support the common rafters on which the covering is laid.

Push.—To strike or force with a thrusting motion.

Pusher.—A sub-foreman, in charge of one gang, who sees that the men do the work assigned to them as rapidly as possible.

Put-log.—A horizontal piece supporting the floor of a scaffold, one end being inserted in a hole left in the masonry for that purpose.

Putty.—A paste composed of soft carbonate of lime and linseed oil, used by glaziers for holding window-glass in a sash.

Putty Joint.—See "Joint."

Putty Lime.—See "Lime."

Q

Quadrangular Truss.—See "Truss."

Quadratic Equation.—An equation of the second degree, or one in which the highest power of the unknown quantity is the second.

Quadruple Block.—See "Block."

Quantities.—The amounts of materials to be handled, expressed in the customary units.

Quarry.—An excavation from which rock is obtained.

Quarry-faced Dressing.—See "Dressing."

Quarry Moisture.—The moisture held in the pores of recently quarried rocks.

Quarry Sap or **Quarry Water.**—See "Quarry Moisture."

Quartered Tie.—See "Tie."

Quartz.—A hard, translucent mineral occurring in either crystalline or massive form. One of the constituents of granite, sandstone, and sand. Chemically, it is the oxide of silicon ($Si\,O_2$).

Quay.—A wharf, *q.v.*

Queen Post.—See "Post."

Queen Post Truss.—See "Truss."

Quenching.—The hardening of steel by dipping in a liquid, such as water or oil. Sometimes molten lead is used for this purpose.

Quick Lime.—See "Lime."

Quick Sand.—A very fine, silt-like sand saturated with water so that it has no stability.

Quick-setting Cement.—See "Cement."

Quiescent Load.—A load that is stationary.

Quirk.—An acute angle or recess. A deep indentation. The incision under the abacus.

Quoin.—An exterior solid angle in masonry. A wedge-like piece of stone or metal. To wedge or raise up.

R

Rabbet.—A half groove along the edge of a board. To cut such a groove.

Rabbeting Machine.—A machine for cutting rabbets in boards.

Rabbet Joint.—See "Joint."

Rabble.—A bar with one end bent at right angles like a poker, used in puddling furnaces.

Rabbling.—Same as "Puddling," *q.v.*

Rack.—A straight iron bar having teeth for engaging those of a gear or a worm. Used to convert rotary motion into rectilinear, or *vice versa.*

Roll Rack.—A rack on which a pinion works.

Worm Rack.—A rack having oblique teeth on which a worm meshes.

Rack and Pinion.—A combination of a rack and a pinion working together.

Rack and Pinion Jack.—See "Jack."

Rack-circle.—A rack bent into the form of a circle.

Racked-back.—Built in steps or offsets.

Racking.—Shaking so that the connecting rivets are loosened and the structure thus permanently injured.

Rack-rail.—Same as "Rack," *q.v.*

Rack Tooth.—See "Tooth."

Radial-arm.—A crank or rod revolving about a centre at one end, such as the crank of a windlass.

Radial Drill.—See "Drill."

Radial Rod.—See "Rod."

Radial Strut.—See "Strut."

Radian.—The unit of circular measure equal to an angle which has a subtending arc of the same length as the radius.

Radius of Curvature.—See "Curvature."

Radius of Gyration.—See "Gyration."

Radius Tool.—See "Tool."

Raft Dog.—See "Dog."

Rafter.—One of the timbers or joists in a roof to which the boards are fastened.

Jack Rafter.—One of the short rafters used in a hip-roof.

Rag-Bolt.—Same as "Bar Bolt," *q.v.*

Rag Wheel.—See "Wheel."

Rail.—A specially shaped bar adapted to a particular purpose. It may be of wood, stone, concrete, or metal. Generally used for supporting vertical loads.

Base of Rail.—The bottom of any rail laid in final position. It generally determines the elevation from which the heights of the various parts of the structure are measured.

Flange Rail.—A rail having on one side an elevated edge or flange to keep the wheels from running off.

Girder Rail.—A deep, heavy rail used for street cars in cities. Its cross-section is similar to that of an I-beam with a projection on top forming the tread of the rail.

Grooved Rail.—Same as "Girder Guard-rail." See "Guard-rail."

Guard-rail.—See "Guard-rail."

Guide Rail.—An additional rail placed inside of and close to one of the ordinary rails to prevent trains from leaving the track on curves.

Handrail.—A railing of concrete, stone, wood, or metal placed on top of posts or balusters to form an open-work construction. Used on the sides of bridges to prevent persons and animals from falling off.

Lorry Rail.—Same as "Lorry Track." See "Track."

[illegible]

before laying.

Rail-brace.—A knee casting [illegible] overturning of rails [illegible]

Rail-chair.—A metal [illegible] tie.

Rail Clamp.—See "Clamp."

Rail-guard.—On English locomotives, [illegible] to within two inches from the [illegible] on the rail. Also sometimes used for [illegible]

Railing.—See "Rail."

Rail Jack.—Same as "Track Jack." See [illegible]

Rail Joint.—See "Joint."

Rail-lift.—A device used on swing spans for [illegible] to clear obstructions on adjacent spans as [illegible]

Rail-lock.—A device used on swing spans for [illegible] after closing the draw.

Railroad Curves.—See "Curves."

Railroad Jack.—Same as "Track Jack," *q.v.*

Railroad Spike.—Same as "Track Spike," *q.v.*

Rail Saw.—See "Saw."

Rail-section.—The cross-section of a rail.

Rail Spike.—Same as "Track Spike," *q.v.*

Rail Splice.—See "Splice."

Rail Tongs.—See "Tongs."

Railway Bridge.—See "Bridge."

Raising Hammer.—See "Hammer."

Rake.—The inclination to the vertical which a [illegible]

Ram.—The hammer of a pile driver; a heavy [illegible] bridge.

Battering Ram.—A beam of timber, generally [illegible] home bridge pins. Sometimes it is made entirely [illegible] large pins are to be driven. A railroad rail is [illegible] ram.

Hydraulic Ram.—An automatic device by which the [illegible] quantity of water is suddenly checked and a portion [illegible] Owing to the momentum of the water, the air in [illegible] the water enters, until the said momentum is [illegible] outlet valve in the supply pipe a new flow is set up [illegible] checked, causing an additional supply to enter the [illegible] crease the previous pressure. This interior air [illegible] out of the discharge pipe which ends at a higher [illegible]

Rammed.—Driven with great force, as a pile is rammed [illegible] of the hammer.

An inclined plane connecting two levels.

Bond.—See "Bond."

Course.—See "Course."

Masonry.—See "Masonry."

Rubble.—See "Rubble."

Tooled Dressing.—See "Dressing."

Masonry.—See "Masonry."

of Stress.—See "Stress."

Pole.—See "Pole."

's Formula.—One of the most widely known formulæ for the design and investigation of columns employed in engineering practice,

$$p = \frac{s}{1 + a\left(\frac{l}{r}\right)^2}$$

where p = allowable unit stress for the column,
s = allowable unit stress for short columns,
a = a constant,
l = length,
and r = radius of gyration in reference to an axis normal to a plane in which flexure takes place.

—A coarse-cut file.

t Rasp.—A rasp having a narrow, rectangular cross-section.

alf-round Rasp.—A rasp having a semicircular cross-section.

et.—A mechanism consisting of a ratchet wheel and a pawl or pawls (or sometimes of a rack and pawl), so arranged that a movement of the pawl in one direction causes a partial revolution of the ratchet wheel while a reverse motion of the pawl has no effect thereon. It is often called a "Click."

at Ratchet, or Steamboat Ratchet.—An apparatus for pulling, consisting of a sleeve having internal, opposing threads at the ends and a ratchet and handle for turning the same. Suitably threaded rods with links and hooks at the outer ends screwed into the sleeve. The turning of the sleeve screws up on the rods causing them to approach each other.

het Coupling.—See "Coupling."

het Drill.—See "Drill."

het Jack.—See "Jack."

het Punch.—See "Punch."

het Reamer.—See "Reamer."

het Wheel.—See "Wheel."

het Wrench.—See "Wrench."

of Strain.—See "Strain."

Formula.—See "Formula."

File.—See "File."

—A cylinder with ends closed, as in a barrel, set on trunnions for rotating. It is used for cleaning small castings by rolling and tumbling them over each other, and also for making abrasion tests of stone, brick, etc.

—Working a rattler.

d Pile.—See "Pile."

—The lines in a force diagram drawn from a selected pole to the ends of the several lines representing the forces in the load line. See "Force Diagram."

—The distance or limit within which a machine can operate, as the reach of a derrick. Also used to denote an unbroken stretch of a stream.

—A passive force set up in opposition to an initial, active force, *e. g.*, the upward pressure on the bottom of a beam resting on a support, equal in amount to the downward pressure from the beam.

[illegible]

[illegible] Reaction.—[illegible]

loads thrown plus [illegible]

Negative Reaction.—A [illegible]

posite direction to a [illegible]

Positive Reaction.—A reaction [illegible]

Upward Reaction.—A reaction [illegible]

same as "Positive Reaction," q.v.

Real Horsepower.—Same as "Indicated [illegible]

Ream.—To enlarge a hole by [illegible]

the side.

Reamer.—A tool having fluted sides with [illegible]

the machine that rotates the [illegible]

Air Reamer.—A reaming machine [illegible]

Close-quartered Reamer.—A [illegible]

shank, for working in restricted spaces. [illegible]

Common Reamer.—A tapered bit with [illegible]

edges.

Countersinking Reamer.—A bit with a [illegible]

tersinking holes.

Expanding Reamer.—A reamer having a device [illegible]

sertion in a hole so as to make an [illegible]

Flat Reamer.—A tapered, flat bit with [illegible]

Fluted Reamer.—Same as "Common Reamer," [illegible]

Hand Reamer.—A reaming machine operated [illegible]

Post Reamer.—Same as "Post-hole Auger," q.v. [illegible]

Ratchet Reamer.—A reamer rotated by a ratchet [illegible]

Reaming.—Cutting with a reamer in order to [illegible]

Reaming-bit.—The cutting tool used with a [illegible]

Reaming Iron.—A round, tapering tool with [illegible]

A reamer. An iron tool used to open the [illegible]

may be more readily calked.

Rebate.—Same as "Rabbet," q.v.

Recarburization.—The adding of carbon in some form [illegible]

in some steelmaking process in order to obtain [illegible]

in the finished product.

Receiving Valve.—See "Valve."

Reciprocal.—The quotient resulting from the dividing [illegible]

reciprocal of that quantity.

Reciprocate.—To move alternately back and forth.

Reconnoisance.—A preliminary investigation in the [illegible]

Rectangle.—A plane, four-sided figure having four [illegible]

equal and parallel.

Rectangular Coordinates.—See "Coordinates."

Red Lead.—See "Lead."

Red Ochre.—See "Ochre."

Red Short.—A condition of brittleness in iron at red [illegible]

Red Short Iron.—See "Iron."

Reduced Load Contour.—A graphical means of [illegible]

ent loads coming upon a structure, so as to give [illegible]

any point by the ordinate to a curve known as the [illegible]

Reduced Scale.—See "Scale."

Reducer.—A pipe coupling for joining pipes of different [illegible]

Reduction.—The production of metal from ore. [illegible]

Redundant Member.—See "Member."

Reef Knot.—See "Knot."

Reel.—A cylindrical drum, spool, or frame upon which is wound a rope, chain, or hose.

Reëntrant Angle.—See "Angle."

Reeve.—To pass a rope through a pulley block or an eye.

Reference Hub.—See "Hub."

Referencing.—A method of fixing the location of a line or point by measuring from it to some permanent object and recording such measuring for future recovery of the said line or point.

Refined Iron.—See "Iron."

Refuge-bays.—Platforms built on the side of a trestle or bridge so that men and hand-cars can be gotten out of the way of approaching trains. Also vertical recesses, large enough for several men to stand up in, left in the side of a wall adjoining a railroad track.

Refusal of Piles.—See "Piles."

Regenerative Furnace.—See "Furnace."

Regular Course.—See "Course."

Regular Curve.—See "Curve."

Re-heating.—Heating a second time; used in tempering steel.

Reinforced Concrete.—See "Concrete."

Reinforced Concrete Floor.—See "Floor."

Reinforcing Bar.—See "Bar."

Reinforcing Plate.—See "Plate."

Relaying Rails.—See "Rail."

Relieving Arch.—See "Arch."

Render.—Same as "Reeve," *q.v.*

Repair Link.—See "Link."

Repeated Stress.—See "Stress."

Rephosphorization.—Adding phosphorus when too much has been removed during the manufacture of steel.

Replacing Switch.—See "Switch."

Repose.—Inaction. Rest.

Angle of Repose.—The angle of inclination to the horizontal of an inclined plane on which a body will be just upon the verge of motion.

Re-railing Guard.—See "Guard."

Reset.—To place in position a second time. The second set in mortar which has been disturbed after setting up the first time.

Residual.—Pertaining to or having the nature of a residuum. Remaining when all required constituents have been removed.

Residual Deformation.—See "Deformation."

Residual Shear.—See "Shear."

Resilience.—The amount of energy which can be stored in an elastic body, up to a given stress per square inch, and which can be given out again by the body as useful work.

Coefficient of Resilience.—The amount of energy absorbed per unit volume of the body. This is affected by the class of deformation whether axial, bending, or torsional; hence there are three kinds of coefficients of resilience.

Work of Resilience.—See "Work."

Resiliency.—The property possessed by an elastic body of absorbing energy as it is deformed and returning same when released.

Resilient.—Having resiliency.

Resistance.—The passive opposition or reaction to any action.

Axis of Resistance.—A line connecting the centres of resistance of successive sections of a member.

[illegible]

Resistance Box.—See "Box."

Resistance Coil.—A coil of wire which [illegible] electric current.

Resistance of Materials.—That property [illegible] of which they oppose the displacement [illegible] a body offers to distortion, or to [illegible] strength of materials. This term is also [illegible] deals with the phenomena of resistance [illegible]

Resisting Moment.—See "Moment."

Resolution.—The resolving of forces into their [illegible]

Resolve.—To analyse a force into its several [illegible] ciple of the "Parallelogram of Forces," [illegible]

Restitution.—The ability of an elastic body [illegible] impact.

Coefficient of Restitution.—The ratio of the [illegible] total momentum before impact, in a system [illegible]

Restoring of Steel.—See "Steel."

Rest Pier.—See "Pier."

Resultant, or **Resultant Force.**—A directed force [illegible] of two or more other directed forces. [illegible]

Resultant Stress.—See "Stress."

Retaining Wall.—See "Wall."

Retardation.—A decreasing of velocity, opposed to [illegible] termed negative acceleration.

Re-tempering of Mortar.—See "Mortar."

Reticular.—Formed like a net; network.

Reticulated Bond.—See "Bond."

Return.—The termination of the drip-stone or hood-[illegible] A 180 degree bend in a pipe or conduit.

Reverberatory Furnace.—See "Furnace."

Reversal.—A change to the opposite kind, sign, pole, or [illegible]

Reversal of Stress.—See "Stress."

Reverse Curve.—See "Curve."

Revet.—To face the bank of a stream with wood, [illegible] erosion.

Revetment.—The facing of wood, mattress, stone, or [illegible]

Revolving Draw Bridge.—See "Bridge."

Rheostat.—An electrical instrument for regulating the [illegible] circuit.

Rib.—An extra and external portion of a body giving it [illegible] The truss or girder of an arch bridge.

Rib.—See "Arch."

Rib.—Same as "Jack Rafter," q.v.

ing Rib.—A rib run longitudinally along the curved trusses in a wooden [illegible] the webs in a shoe, casting, or baseplate.

rtening.—The contraction in an arch rib due to the axial stress set up by the ding or by a rise in temperature.

Lime.—See "Lime."

—To fit out with what is needed. To put a machine in condition for using.

g.—The ropes, pulley-blocks, etc. needed to fit out a derrick or similar machine.

Arch.—See "Arch."

Forward.—The American method of building a skew arch by constructing a number of short right arches adjoining each other, each one springing from a skewback which is ahead of or back of its neighbor. This is to avoid the use of spiral joints between the voussoirs, a construction which prevails in European practice.

Handed Nut.—Any nut having a right-handed thread.

Handed Screw.—See "Screw."

Handed Thread.—See "Thread."

g Moment.—See "Moment."

line Formula.—A column formula in which the allowable unit working stress is made to vary as the first power of $\frac{l}{r}$ thus—

$$p = a - b\frac{l}{r}$$

where p = allowable working stress,
a = allowable unit stress for short columns,
b = a constant.
l = length,
and r = the least radius of gyration.

of Way.—The land or water rights necessary for the roadway and its accessories.

—Resisting change of form; stiff; firm; not pliant or flexible.

Body.—A body possessing rigidity or stiffness.

ty.—The quality of being rigid or resistant to distortion.

tive Rigidity.—A comparison of the rigidities of two bodies.

Bearing.—See "Bearing."

Bearing Draw.—See "Draw."

Bearing Turntable.—See "Turntable."

Saw.—See "Saw."

gall.—A defect in timber due to a bruise in the bark that causes a hard spot in the wood to which the succeeding layers of wood do not adhere.

—A solid generated by the revolution of a closed curve about an axis in the plane of the said curve, but lying outside thereof.

h ring.—See "Arch."

y Ring.—A ring attachment on a derrick, etc., for connecting guy lines.

ing Ring.—An elastic metallic ring used for packing the piston of an engine.

Ring.—Same as "Pile Band," q.v.

lt.—Same as "Eye Bolt," See "Bolt."

hain.—A chain having rings at the ends and often one or more intermediate rings.

Course.—See "Course."

g.—See "Dog."

ly.—See "Dolly."

—See "Heart."

[illegible]

or around a pier to prevent [illegible]

[illegible]—See "[illegible]."

Rise.—The vertical distance between [illegible]

Rise of an Arch.—See "Arch."

Risers in Moulds.—An excess of metal [illegible] keep the mould full while the metal [illegible]

River Gravel.—Smooth, rounded stones, [illegible] several inches in diameter.

Rivet.—A short iron or soft steel rod [illegible] into a proper hole, and the other end [illegible] formed.

Calked Rivet.—A rivet which has not been [illegible] hole, but to which a seeming tightness [illegible] head under with a cold cut or similar tool.

Countersunk Rivet.—A rivet used in [illegible] hot, is hammered down to fill the counter[illegible]

Field Rivet.—A rivet driven in the field [illegible]

Flat-head Rivet.—A rivet which has the [illegible]

Grip of Rivet.—The thickness of the plates [illegible]

Pitch of Rivets.—The distance between the [illegible]

Plugged Rivet.—Same as "Calked Rivets," *q.v.*

Shop Rivets.—A rivet driven in the shop.

Snap-head Rivet.—A rivet having its head [illegible]

Stitch Rivets.—Rivets placed at intervals [illegible] them together and give lateral stiffness.

Rivet Cutter.—See "Cutter."

Riveted Girder.—See "Girder."

Riveted Joint.—See "Joint."

Riveted Truss.—See "Truss."

Riveter.—One who drives rivets. A riveting machine [illegible]

Air Riveter.—A riveting machine which is operated [illegible]

Alligator Riveter.—A jaw riveter worked by the [illegible]

Bull Riveter.—A form of stationary, yoke riveter [illegible] a large air cylinder at the end of one of the arms [illegible] stroke in a horizontal direction and the former on the [illegible] the shank and forms the head in one movement of [illegible]

Horseshoe Riveter.—A form of yoke riveter hung [illegible] be readily moved about the shop to reach different [illegible]

Hydraulic Riveter.—A riveting machine operated by [illegible]

Pneumatic Riveter.—Same as "Air Riveter," *q.v.*

Steam Riveter.—A shop riveter driven by steam.

Toggle Riveter.—A riveting machine using a toggle [illegible] required to upset the stem and form the rivet head [illegible]

Yoke Riveter.—A machine riveter in which the [illegible] an elongated, narrow yoke and to the anvil at the [illegible] reaching of rivets remote from the edge of the plates [illegible]

Rivet Forge.—See "Forge."

Rivet Hammer.—See "Hammer."

Rivet-hole.—The hole through which a rivet is driven [illegible]

Riveting.—The fastening of plates or parts together by [illegible]

Riveting.—The making of a butt-joint by using cross-plates and rivets.

n Riveting.—A term applied to riveting where the rivets in the second or succeeding rows are placed directly back of those in the first row or preceding rows.

Riveting.—Same as "Staggered Riveting," *q.v.*

ble Riveting.—A term applied to riveted joints in which a double row of staggered rivets is used for a lap joint and two double rows for a butt joint—one double row on each side of the joint.

Riveting.—Driving rivets by hand.

Riveting.—The making of a lap-joint by using rivets to fasten the overlapping ds of the plates.

le Riveting.—A term applied to lap-joints in which one row of rivets only is ed to fasten the plates.

gered Riveting, or Zigzag Riveting.—Rivets set in zigzag order, or so spaced that rivets in one row are opposite the centres of the spaces of the adjoining rows.

g Burr.—See "Burr."

g Gang.—See "Gang."

g Gun.—See "Gun."

g Kit.—See "Kit."

Rod.—See "Rod."

Set.—Same as "Rivet Snap." See "Snap."

Snap.—See "Snap."

Steel.—See "Steel."

stem.—The shank or that portion of the rivet under the head.

Tongs.—Tongs used by field riveters for throwing and placing hot rivets.

-bed.—In railroading the finished surface of the roadway on which the ballast and track rest. In highways that of the roadway which receives either the concrete base or the broken stone.

Roller.—See "Roller."

way.—That part of the road over which the vehicles pass.

ear Roadway.—The horizontal distance, measured perpendicularly to the plane of the trusses, between the inner edges of the batter braces. Sometimes measured between the faces of curbs or guard rails.

Drill.—See "Drill."

er.—A casting or built-up steel frame fastened to the end of a truss or column to permit of a slight rotation.

r-arm.—An arm on a rock shaft, as in the valve mechanism of a steam engine.

r Bearing.—See "Bearing."

r Bent.—See "Bent."

r End.—The end of a truss or column resting on a rocker.

aced Dressing.—See "Dressing."

Movement.—A slipping movement of a ledge of rock, usually caused by water the horizontal seams.

Shaft.—See "Shaft."

Work.—A general term for "Masonry," *q.v.* Also see "Work."

—A long, round piece, strip, or bar of metal. A surveyor's tool for finding the difference in elevation between two points, used in connection with a level. As ordinarily constructed, it consists of two flat strips of wood, arranged to slide upon each other and having the exposed faces graduated into feet and tenths, or in some cases, feet, inches, and fractions of an inch.

ect's Rod.—A very light and simple sliding level rod having two equal parts each seven-eighths of an inch square. When closed it is about five and a half feet long. It carries a target and is graduated into feet, inches, and fractions of inches.

[illegible] Rod.—The [illegible]
transformed and [illegible]

[illegible] Rod.—A term [illegible]
bridge builders) to denote a [illegible]
two adjacent posts of the same [illegible]
the posts at the middle in order that [illegible]
benefit derived therefrom is more [illegible]

King Rod.—An iron rod used to take the [illegible]

Lateral Rod.—A tension diagonal of a lateral [illegible]

Levelling Rod.—A surveyor's graduated [illegible]

Metric Rod.—A level rod graduated to [illegible]

New York Rod.—A level rod having two [illegible]
engine-divided into feet and decimal parts [illegible]
burned into the hard wood and can be [illegible]
necessitating the setting of the target. [illegible]

Philadelphia Rod.—A level rod having two [illegible]
graduations are painted on as well as the [illegible]
be read at considerable distances without [illegible]
cision is not required, this rod is well adapted [illegible]

Piston Rod.—A steel rod connecting the piston [illegible]

Plain Rod.—A level rod made of one piece of [illegible]
graduated in feet and decimal parts thereof. [illegible]

Portal Rod.—A tension member in the portal [illegible]
quated type of construction.

Radial Rod.—A rod connecting the roller of a [illegible]
casting.

Rivet Rod.—A bar of soft iron or steel from which [illegible]

Sounding Rod.—A rod or pipe used for making [illegible]
into the soil.

Spider Rod.—Same as "Radial Rod," *q.v.*

Stadia Rod.—A rod divided into feet and tenths [illegible]
visible at long distances. It is used in connection [illegible]
transit to read distances directly. Sometimes a [illegible]
rod. Special stadia rods are frequently termed [illegible]

Stay Rod.—A stiffening rod used in the interior of a [illegible]

Suspension Rod.—One of the rods attached to the [illegible]
support the floor system.

Sway Rod.—Any rod used for sway-bracing.

Telemeter Rod.—Same as "Stadia Rod," *q.v.*

Tension Rod.—Any rod subjected to tension.

Tie Rod.—A rod connecting two parts of a structure [illegible]
Howe truss bridge. Also a bar or rod used to [illegible]
track to prevent their spreading.

Rod.

Troy Rod.—A level rod made of two sliding pieces and carrying two targets, one on the top and the other on the bottom, the upper target being fixed to the extension member and the lower target arranged to move on the main rod.

Truss Rod.—A rod used for trussing or bracing a beam, also called Hog Chain. Any rod employed as a part of a truss.

Upset Rod.—A rod having one or both of its ends enlarged by an upsetting process.

Vibration Rod.—A tension diagonal for vertical or portal sway-bracing used in light highway bridges. Such bracing is far inferior to rigid sway-bracing.

Rodman.—The man in a level party who carries and manipulates the level rod.

Rolled Beam.—See "Beam."

Rolled Channel.—See "Channel."

Rolled Iron.—See "Iron."

Rolled Pile.—See "Pile."

Rolled Steel.—See "Steel."

Roller.—Any short, round bar put under an object to facilitate its movement.

Conical Roller.—A cone-shaped roller placed under an object in order to provide for its rotating motion. Used under rim-bearing swing spans.

Expansion Rollers.—A group of steel cylinders nested in a box or suitable frame placed under the shoe of a span to facilitate its movement during temperature changes and loading.

Friction Rollers.—Rollers placed between moving bodies or around a revolving shaft to reduce the friction.

Guide Rollers.—A roller on a fixed axle serving as a guide to anything passing along in contact with it.

Indentation Roller.—A hand tool for roughening concrete surfaces, consisting of a roller with teeth mounted in a frame attached to a handle.

Road Roller.—A heavy steam or horse roller used in the construction of macadamized roads and pavements.

Segmental Roller.—A roller composed of two opposing circular segments and an intermediate connecting web; used under bridge-shoes.

Roller-and-thimble Chain.—See "Chain."

Roller Bascule.—See "Bascule."

Roller Bearing.—See "Bearing."

Roller-bearing Bascule.—See "Bascule."

Roller Box, or **Roller Frame.**—See "Box."

Roller Plate.—See "Plate."

Rolling Draw Bridge.—Same as "Pull-back Draw Bridge." See "Bridge."

Rolling Friction.—See "Friction."

Rolling Hitch Knot.—See "Knot."

Rolling Lift Bridge.—See "Bridge."

Rolling Load.—Same as "Moving Load." See "Load."

Rolling Mill.—Same as "Mill," *q.v.*

Rolling Stock.—All of the various classes of cars and engines used on a railroad.

Roll Rack.—See "Rack."

Rolls.—A machine consisting of several rollers, mounted in a frame, having intermeshing gears producing a positive motion; used in shaping steel ingots into bars, beams, angles, etc.

Puddle Rolls.—A machine having heavy, grooved rollers, between which lumps of plastic iron, taken direct from the puddling furnace and hammered into rough bars, are first rolled.

Straightening Rolls.—Rolls in a steel mill used for rerolling bars, beams, channels, etc., which had been bent during manufacture.

Roman Cement.—See "Cement."

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Cable Rope.—[illegible]

Guy Rope.—A rope used as a

Hoisting-tackle Rope.—[illegible]

[illegible] block in the top of a

Used to raise weights,

Manila Rope.—Rope made from

of the same genus as the banana,

Steel Rope.—Rope made from steel

Standing Rope.—A rope fastened

Wire Rope.—A rope made of small

hemp centre.

Rope Bridge.—See "Bridge."

Rope Clamp.—See "Clamp."

Rope Guard.—See "Guard."

Rope Lashing.—See "Lashing."

Rope Sling.—See "Sling."

Rose Bit.—See "Bit."

Rose Drill.—See "Drill."

Rose Jet.—See "Jet."

Rosendale Cement.—See "Cement."

Rosette.—An ornamental device resembling a

Rot.—Decay, decomposition.

Dry Rot.—A decay affecting dry timber,

Wet Rot.—A decay affecting timber, caused

Rotary Crane.—See "Crane."

Rotary Furance.—See "Furnace."

Rotary Pump.—See "Pump."

Rotating Draw.—Same as "Revolving Draw Bridge."

Rotating Drill.—See "Drill."

Rotation.—Turning around on an axis or centre.

Axis of Rotation.—A line passing through the

to the plane of rotation.

Centre of Rotation.—The point of a rotating body

the other points revolve around it.

Negative Rotation.—Rotation in a direction opposite

Positive Rotation.—Rotation in the same direction

Rotten Knot.—See "Knot."

Rough Ashlar.—See "Ashlar."

Rough Dressing.—See "Dressing."

Rougher.—A man or a machine that does the prelim

object.

Rough Finish.—See "Finish."

Rough-pointed Dressing.—See "Dressing."

Round Knot.—See "Knot."

Round Pile.—See "Pile."

Rounds.—Round bars in the bracing system of a high

ladder.

Round Turn and a Half Hitch.—See "Knot."

Rowlock Bond.—See "Bond."

Rubbed Dressing.—See "Dressing."

ed Stone.—Same as Rubbed Dressing. See "Dressing."

er.—A man or a machine that smooths stone. An elastic gum.

aded Rubber.—A pliable eraser used to clean drawings.

er Hose.—See "Hose."

er Packing.—See "Packing."

ble.—Rough, broken, one-man-size stone used in rubble masonry.

oken Coursed Rubble, or Broken Range Rubble.—Rubble masonry laid in partial courses and having abrupt changes in thickness thereof.

ursed Rubble.—Rubble masonry laid in courses which may or may not vary in thickness.

ndom Rubble or Uncoursed Rubble.—Rubble masonry laid up without regard to courses.

bble Masonry, or Rubble Work.—See "Masonry."

—An annular ridge formed on a shaft or other piece, commonly at a journal, to prevent motion endwise.

e.—A flat, straight stick or strip of metal graduated into linear units for convenience in measuring or laying off distances.

hrink Rule.—A rule having slightly exaggerated divisions (an excess of one-eighth of an inch in twelve inches) to compensate for the shrinkage of metal in cooling. Used by pattern makers.

ide Rule.—See "Slide-rule."

e Joint.—See "Joint."

or Runway.—A line of planks laid down for wheeling or walking over. Used by constructors.

dle.—The step of a ladder. Same as round.

g.—The round or step in a ladder.

g-head.—The upper end of a floor timber.

ner.—In foundry practice, the channel through which molten metal is run into the mould.

ning Block.—See "Block."

ning-expense.—Expenditures incurred during the operation of the plant or structure only. They are equal to the sum of operation and maintenance outlays.

ning Hitch.—A form of "Running Knot." See "Knot."

ning Knot.—See "Knot."

-off.—The water which flows from a drainage basin.

way.—A passageway. Also see "Run."

ture.—To break apart. The act of breaking apart.

gle of Rupture.—The angle made with the transverse axis by the break in a test piece.

nt of Rupture.—That joint in a voussoir arch for which the tendency to open at the extrados is the greatest.

Modulus of Rupture.—The unit stress at which a piece fails.

ane of Rupture.—The plane along which failure occurs.

ture Line.—See "Line."

—An oxidization of a metal.

on Rust.—The oxide of iron.

Cement.—See "Cement."

ic or Rusticated Dressing.—See "Dressing."

Joint.—See "Joint."

S

—A bag. To discharge an employee.

ng-sack.—A bag made of coarse, heavy sacking of jute or hemp.

[illegible]

load above a certain

Safety Rail.—A guard rail, as

Safety-stop.—An automatic

machine from falling in case the

Sag.—The greatest deviation from a

undergoes, such as a rope or a chain.

Sal-ammoniac.—Commercial

Salient.—A portion projecting beyond

Salt.—Chloride of sodium (NaCl). Used

lower the freezing point of the mixture.

Salvage.—That portion of a structure or

after having been used.

Salvage-value.—The price for which a

Sampling-iron.—An iron bit or spoon

sample of the contents. Used by cement

Sand.—Broken down, water worn, crystalline

inch in diameter.

Coarse Sand.—Sand rejected by a number

Fine Sand.—A sand containing more than

a No 40 sieve. Usually undesirable for

Green Sand.—A sand fresh from the pit.

Iron Sand.—Sand containing considerable

Quick Sand.—A fine, smooth-grained sand.

Sharp Sand.—A sand having sharp-edged

Slag Sand.—Slag ground to the consistency of

mortar or concrete.

Sand-bag.—A bag filled with sand, used to close a

Sand Bar.—See "Bar."

Sand Bearing.—See "Bearing."

Sand-blast.—A device for projecting sand particles, at

by means of compressed air. Used in cleaning

Sand Briquettes.—See "Briquettes."

Sand Cement.—See "Cement."

Sand-hog.—A term applied to any laborer working

of piers.

Sand-hog House.—A house near the bridge site, used by

Sand Hoist, or **Sand Lift.**—See "Hoist."

Sand Pile.—See "Pile."

Sand Pump.—See "Pump."

Sand Screen.—See "Screen."

Sand Sieve.—See "Sieve."

Sandstone.—See "Stone."

Sand Trap.—See "Trap."

Sandwich Girder.—See "Girder."

—The fluid which circulates in plants, trees and other vegetation. Also [illegible] oisture in newly quarried rock. Same as "Quarry Sap," q.v.

y.—A condition of steel as indicated by the surface of fracture where the grains are very coarse and bright.

Tie.—See "Tie."

Wood.—See "Wood."

Brace.—A horizontal member secured to the posts or piles of a bent between the ap and sill.

—A cutting tool consisting of a thin blade or sheet of steel having teeth on one r both edges and handles or other attachments for giving it motion.

d Saw.—An endless, narrow band or ribbon of steel with a serrated edge, passing over two large wheels which give it a continuous uniform motion instead of the reciprocating action of a jig-saw, also called a "belt saw" or "endless saw."

Saw.—A circular saw; so called from its sound when in action.

rcular Saw.—A thin circular plate of steel, with teeth cut in the edge, mounted on a shaft and rotated at a high speed.

ld Saw.—A toothless, soft-iron disk rotating at a high speed, used in mills for cutting steel beams.

ross-cut Saw.—A saw adapted by the filing and setting of its teeth to cut across the grain of the wood.

k Saw.—A small frame hand saw having a narrow blade with fine teeth set close together and well tempered. Used for sawing metals.

nd Saw.—A saw consisting of a blade of steel with a serrated edge, and having a handle at one end adapted for use by one hand.

t Saw, or Iron Saw.—A circular saw for hot steel or iron shapes.

g Saw.—A reciprocating sawing machine having a narrow vertical blade set in a frame which has an oscillating motion.

etal Saw.—A saw having a blade tempered hard enough to cut metals.

t Saw.—A large hand saw worked vertically by two men, one of whom (the pitman) stands in a pit.

ail Saw.—A saw used at the mills for cutting rails.

n Saw.—A type of circular saw in which the teeth are a part of a detachable ring that is mounted on a central disk.

p Saw.—A saw having teeth with small set and large rake used for sawing along the grain of timber.

ne Saw.—A tool or machine for cutting stone, consisting of a flat blade of iron having a reciprocating motion, and fed with sand by a stream of water, the sand doing the cutting.

Wide Cross-cut Saw.—A cross-cut saw with a long, wide blade having a handle on each end so that it can be operated by two men.

b.—A plank used in making a splice between two timbers.

on Scab.—A scab or scab-plate made of iron.

bed.—The condition of being joined by a scab or scabs.

bing Hammer.—See "Hammer."

bled Dressing.—A form of "Masonry Dressing." See "Dressing."

Plate.—Same as "Scab," *q.v.*

fold.—A temporary platform or staging for supporting workmen during the building of a structure.

winging Scaffold.—A scaffold hung on ropes fastened to overhead supports.

olding.—A general term covering all the scaffolds on a job.

e.—A graduated stick of wood or metal for measuring or laying off distances. To measure with a scale. The ratio of the linear dimensions of a drawing to the corresponding dimensions of the actual object so represented. A coating of oxide which forms on the surface of heated metal.

itects' Scale.—A scale in which the units are divided duodecimally.

[illegible]

[illegible]

[illegible] Scale.—

Enlarged Scale.—An

Exaggerated Scale Drawing.—A profile. But little used by

Flat Scale.—A scale made on a flat

Hammer Scale.—A scale of oxide

Iron Scale.—A loose coating of oxide of forging.

Natural Scale.—A full-sized delineation aggerated Scale."

Reduced Scale.—An undersized delineation

Triangular Scale.—A scale made on a ferent sets of graduations.

Unexaggerated Scale.—A term used to is the same in all directions.

Scaling Hammer.—See "Hammer."

Scarf Joint.—See "Joint."

Scarf Weld.—See "Weld."

Scarp.—A steep slope.

Schedule-prices.—The prices stipulated in a the furnishing of materials at unit rates.

Schwedler Truss.—See "Truss."

Scoop.—A special type of bucket having a dredging. A spade having the sides turned

Scoop Dredge.—See "Dredge."

Scooping.—The act of dredging with a scoop.

Scotch.—To chip; to hack. To block, or prop up.

Scour.—A clearing out or removal of silt and current. To remove such material in that manner.

Scow.—A flat-bottom boat.

Dump Scow.—A drop-bottom scow from which

Scrag.—To straighten a spring, etc., which has been and releasing.

Scrap.—Discarded material. Junk.

Scraper.—A tool for scraping up loosened earth and or mules and guided by handles attached to its rear,

Scrap Iron.—See "Iron."

Scrap Pile.—A heap or a pile of junk.

Scratch Awl.—See "Awl."

Screeds, or Screed-iron.—Strips of wood used for gauges, angle iron on legs, or other device, which, in concrete to serve as a guide in forming the top of the slab.

Screen.—A large sieve; device for sifting and separating

Sand Screen.—A sieve for sifting sand.

Screening.—The act of sifting and separating particles by material passing through the screen—generally used

Granite Screenings.—Small particles of granite screened

Screw.—A cylindrical bar on which has been formed a

Cap Screw.—A screw which has a square or hexagonal of the screw, thereby providing a shoulder for bearing

Female Screw.—A hollow cylinder having an interior

Guide Screw.—A screw for directing or regulating

Jack Screw.—Same as "Screw Jack." See "Jack."

Screw.

Lag Screw.—A large-sized wood screw with a square head larger than the shank for convenient turning with a wrench, and having a special thread to increase the holding power.

Left-handed Screw.—A screw having a left-handed thread. See "Thread."

Machine Screw.—A screw which has a straight shank and an enlarged head providing a shoulder for bearing. A slot in the head affords the means for turning with a screwdriver.

Male Screw.—A screw having an exterior thread.

Micrometer Screw.—Same as "Micrometer," *q.v.*

Right-handed Screw.—A screw having a right-hand thread. See "Thread."

Set Screw—A type of screw similar to a cap screw but without a shoulder under the head and with a cup-shaped end for a better grip on the object.

Square-threaded Screw.—Any screw having square threads.

Thumb Screw.—A screw having flat wing-like projections on the head for convenience in turning with thumb and fingers.

Wood Screw.—A screw having a tapering shank and either a flat or a rounded head with a slot for turning by means of a screwdriver.

Screw-adjustment.—An adjustment in which motion is provided by a screw.

Screw Bolt.—See "Bolt."

Screw Clamp.—See "Clamp."

Screw Disc.—See "Disc."

Screw Dolly.—See "Dolly."

Screw-end.—The threaded end of a bolt.

Screw Jack.—Same as "Jack Screw," See "Jack."

Screw Stock.—Same as "Die Stock." See "Stock."

Screw Pile.—See "Pile."

Screw Thread.—The thread on a screw.

Screw Track-spike.—See "Spike."

Scribe.—To trim off the edge of a board, etc., so as to make it fit closely at all points to a certain line; to mark with a scriber.

Scriber.—A sharp-pointed tool for marking metal.

Scribing Awl.—See "Awl."

Scrids.—Same as "Screeds."

Scurf.—To flake off, or the material which flakes off. Dross.

Seam.—A crack in a badly rolled steel section. A crack or parting in rock.

Crow-foot Seam.—A vein in rock containing dark-colored, uncemented material.

Dry Seam.—An open crack in a rock.

Lap Seam.—A seam in which the separate parts extend over each other.

Seasoning.—The process of becoming fit for use, as lumber becoming dry and hard through exposure.

Seat Angle.—See "Angle."

Secant.—Any line cutting another line. A trigonometric function defined by the ratio of the hypothenuse of a right-angled triangle to its base, in reference to the acute angle adjacent to the said base.

Second-class Masonry.—See "Masonry."

Secondary Member.—See "Member."

Secondary Stress.—See "Stress."

Secondary Strut.—See "Strut."

Secondary Truss.—See "Truss."

Secondary Truss Member.—See "Member."

Second Set.—See "Set."

Section.—The trace on a secant plane made by the object cut. Sometimes improperly used for a member or segment thereof.

Longitudinal Section.—A section

long axis of the member.

Meridian Section.—A section of

containing a diameter.

Net Section.—Used improperly for

area of a member after the rivet-hole

Skew Section.—A section of a member

Transverse Section.—Same as "

Uniform Section.—The condition of having

of the secant plane.

Sectional Area.—See "Area."

Section-modulus.—The moment of inertia of the

by the distance from the centre of gravity

Section Required.—The section area of a

force acting on the said member.

Sector.—That portion of a circle included

ing arc.

Sediment.—The fine material which settles to the

Seepage.—The oozing or percolation of water

thus percolated.

Segment.—That portion of a circle lying between

a member.

Track Segment.—A part or unit of a circular track

bearing draw-span.

Segmental.—Pertaining to a segment.

Segmental Arch.—See "Arch."

Segmental Roller.—See "Roller."

Seize.—To bind a journal in its bearings by over

or windings of cord, line, or small rope.

Self-hardening Steel.—Same as "Mushet Steel," *q.v.*

Semaphore.—An apparatus for making signals with

Semi-cantilevering.—A method of erecting a span without

from an adjacent span, or adjacent spans, or from

Set.

- **Final Set, or Hard Set.**—The degree of hardening of cement mortar as determined by the non-penetration of the Vicat needle.
- **Initial Set.**—The beginning of the hardening process of cement mortar as determined by the Vicat needle.
- **Permanent Set.**—Same as "Hard Set" in cement, *q.v.* Also the residual deformation in a member when the load is removed.
- **Rivet Set.**—A tool for shaping the heads of rivets. Often called a snap.
- **Second Set.**—The hardening of mortar that has once partially hardened and which has been disturbed before getting its final set.

Set Pin.—Same as "Dowel," *q.v.*

Set Screw.—See "Screw."

Sewer Brick.—See "Brick."

Shackle.—A U-shaped attachment for large pulley-blocks replacing the customary hook.

- **Anchor Shackle.**—A bolt or clevis with two eyes and a screw bolt and key, used for securing a cable to the ring of an anchor; also employed for coupling chains.
- **Splicing Shackle.**—A shackle in the end of a length of chain through which the end of a rope is taken and spliced.

Shackle Bar.—See "Bar."

Shackle Joint.—See "Joint."

Shade.—A painter's term descriptive of that difference between colors which results from a variation in luminosity only, the other color constants being essentially equal.

Shaft.—A well-like opening, nearly or quite vertical, in cribs and caissons; used for hoisting material through or for the passage of workmen. A long, cylindrical bar capable of rotating and transmitting torque.

- **Air Shaft.**—A tube, pipe, conduit, or passageway for conveying air.
- **Cam Shaft.**—A shaft on which a cam is mounted.
- **Crank Shaft.**—A shaft having one or more cranks attached.
- **Driving Shaft.**—A shaft from the driving wheel communicating motion to machinery.
- **Excavating Shaft.**—A shaft or hole through which excavation is carried on.
- **Jack Shaft.**—In rolling-mill machinery, a shaft that takes the power from the engine shaft and transmits it by pinions and spindles to the rolls.
- **Junction Shaft.**—A spindle in a rolling mill.
- **Main Shaft.**—A principal shaft used in the transmission of power.
- **Pinion Shaft.**—A shaft carrying a pinion for transmitting motion.
- **Rock Shaft.**—A shaft which makes part of a revolution each way instead of rotating continuously in the same direction.
- **Supply Shaft.**—A passageway in a crib and caisson for the transferring of supplies.
- **Working Shaft.**—A passageway in a crib and caisson for workmen.
- **Worm Shaft.**—The shaft or axle passing through a worm.

Shaft Bearing.—See "Bearing."

Shaft Coupling.—See "Coupling."

Shafting.—A general term for a number of shafts connected up to form a system. Rounds used for making shafts.

- **Cold-rolled Shafting.**—Shafting on which the final rolling was done after the metal had somewhat cooled.
- **Turned Shafting.**—Shafting which has received its truing-up and final finish by being turned in a lathe.

Shafting Box.—See "Box."

Shakes.—Splits or checks in timber which usually cause a separation of the wood between the annular rings.

- **Heart Shake.**—A fissure in the heart of a timber due to growth.

[illegible]

[illegible] the back.

Shale.—A hard, clay-like formation

Shank.—That part of a tool connecting

Shank Mortar-mixer Hoe.—See

Shank Street-hoe.—See "Hoe."

Shape.—Any rolled beam or bar used in

Shaper.—A machine tool for planing

Shape Steel.—Same as "Shape," *q.v.*

Sharp Sand.—See "Sand."

Shay Locomotive.—See "Locomotive."

Shear.—To slide one part of a body upon

opposition to a shearing action.

Counter Shear.—A shear in opposition to

Double Shear.—A sliding on two different

End Shear.—The shear at the end of a

Longitudinal Shear.—A shear parallel to the

Negative Shear.—A relative term usually applied

motion.

Positive Shear.—A relative term usually applied

motion.

Residual Shear.—A permanent shear deformation

Single Shear.—A sliding, or a tendency to slide,

Transverse Shear.—A shearing action parallel to

Shear Diagram.—See "Diagram."

Sheared Edge.—An edge of a plate which has been

Sheared Plate.—See "Plate."

Shearing Machine.—A machine for shearing metal,

operating against a fixed cutting edge.

Shearing Modulus of Elasticity.—See "Elasticity."

Shearing Strain.—See "Strain."

Shearing Strength.—See "Strength."

Shearing Stress.—See "Stress."

Shears.—Same as "Shearing Machine," *q.v.*

Angle Shears.—A shearing machine especially adapted

Hoisting Shears, or Sheers.—A support made of two

near one end and are pivoted so that they may be

hoisting gin poles.

Shear Steel.—See "Steel."

Sheathing.—A covering or casing of planks. Used on

Sheave.—A wheel with a grooved face for carrying a rope

Derrick Sheaves.—The stationary sheaves in the mast

Head Sheaves.—The sheaves mounted on the head block

Snatch-block Sheave.—The grooved wheel in a snatch-block

Sheave-stand.—A frame or support for a sheave and its

Sheep-shank.—See "Knot."

Sheet-bend.—See "Knot."

Sheet-bend with a Toggle.—See "Knot."

Sheeting.—Same as "Sheathing," *q.v.*

Sheet Iron.—See "Iron."

Sheet Lead.—See "Lead."

Sheet Packing.—See "Packing."

Sheet Piles.—See "Pile."

Piling.—See "Piling."

—A flat projection from a wall or column.

Angle.—Same as a "Seat Angle." See "Angle."

—A hollow cylinder for piers. A casing. A framework not filled in.

c.—A gum made from a resinous exudation of an East Indian scale insect. When mixed with alcohol it forms a varnish which is much used in the arts and is termed "Shellac."

ld.—A bulkhead or contrivance to protect workmen and property, used in certain classes of underground work.

—A relay or change of workmen.

-boss.—The foreman of a shift.

—A small piece of wood or metal placed between two parts or members of a structure to bring them to a desired relative position.

-bolt.—A bolt used to fasten a shim in place.

ming Plate.—See "Plate."

gle.—A thin, wedge-shaped piece of wood used for roof covering, laid overlapping each other. A steel plate employed in making a splice. To make a compound splice by cutting the component parts at different places.

le Splice.—See "Splice."

Auger.—See "Auger."

ping.—A general term applied to vessels collectively. The act of despatching goods.

ping-bill.—A list of the articles shipped.

ping Invoice.—See "Invoice."

ping-list.—A list of all the articles to be shipped.

ping-weight.—The weight of the articles shipped, including that of the wrappings and packing.

ck.—A jar; the effect of a blow; the sudden absorption of energy.

e.—That part or detail of a span which transfers the load from the end pin to the bearing plate or to the intervening rollers. Also a cast-iron point used on piles when driving them through hard ground.

Pile Shoe.—A conical iron point with projecting prongs, by means of which it is fastened to the end of the pile before driving.

e Block.—See "Block."

e Pin.—See "Pin."

e Plate.—See "Plate."

ot.—Same as "Chute," *q.v.*

—The place where bridge spans are fabricated.

achine Shop.—A shop for metal turning, planing, and drilling.

attern Shop.—A wood-working shop in which patterns are made.

Drawing.—See "Drawing."

Rivet.—See "Rivet."

re.—The land adjacent to a body of water. A support or a prop. To support with a shore.

re Span.—See "Span."

ring.—A general term covering a system of shores or props.

rt Column.—See "Column."

rt-leaf Yellow Pine.—See "Pine."

rt Ton.—See "Ton."

t.—Small lead balls, used for gradually applying a load in a certain style of testing machines. An explosion in blasting.

lder.—The bearing surface perpendicular to a member produced by a projection or a recess in such member.

lder Block.—See "Block."

e Joint.—See "Joint."

[illegible]—A walk for pedestrians [illegible]

[illegible]—Same as "Side Track." [illegible]

[illegible] Process.—A process for [illegible] which utilizes the heat of the [illegible] passageways for air and gas [illegible] required, being used alternately. [illegible] metal, the other is being [illegible] twenty or thirty minutes a [illegible]

Siemens's-Martin Process.—The acid [illegible]

Sieve.—An apparatus consisting of wire [illegible] work of meshes through which a granular [illegible]

Gravel Sieve.—A coarse-meshed sieve [illegible]

Sand Sieve.—A sieve with meshes less [illegible] sand.

Standard Sieve.—A term applied to sieves [illegible] one hundred meshes per lineal inch and the [illegible] inch.

Silica.—A dioxide of silicon (SiO_2). It occurs in [illegible]

Silicate of Lime.—See "Lime."

Bicalcic Silicate.—A union of calcium and silica [illegible]

Silicious.—Having the nature of silica or pertaining [illegible]

Silicon.—A chemical element of the non-metallic [illegible]

Silky Fracture.—See "Fracture."

Sill.—The lower horizontal member of a framed bent.

Bank Sill.—A sill placed on the end of an embankment [illegible] wooden trestle.

Cap Sill.—A sill placed on piles.

Intermediate Sill.—A horizontal member in the plane of [illegible] the elevations of cap and sill, to which the posts [illegible]

Mud Sill, or Sub Sill.—A sill placed on short cross [illegible] support a framed bent.

Silt.—A fine, earthy sediment deposited by muddy water.

Simple Beam.—See "Beam."

Simple Curve.—See "Curve."

Simple Knot.—See "Knot."

Simple Span.—See "Span."

Simplex Pile.—See "Pile."

Sine Curve.—See "Curve."

Single-acting Pump.—See "Pump."

Single Block.—See "Block."

Single Cancellation.—See "Cancellation."

Single Concentration.—See "Concentration."

Single Intersection.—Same as "Single Cancellation." [illegible]

Single Intersection Truss.—See "Truss."

Single Lacing.—See "Lacing."

Single Latticing.—See "Latticing."

Single Lip Screw Auger.—See "Auger."

Single Locomotive Excess Load.—See "Locomotive Excess Load."

Single Punch.—See "Punch."

Single Riveting.—See "Riveting."

Single Shear.—See "Shear."

Single Shear Steel.—Same as "Shear Steel," *q.v.*

Single Track.—See "Track."

Sinking.—The process of lowering cribs, caissons, and piers to their foundations.

Sinking Fund.—A fund built up during a period of time to provide a given sum of money at the end of that period, by making at regular intervals uniform deposits which draw compound interest.

Siphon.—A bent tube or pipe having unequal legs, employed for drawing off water when the summit of the bend is higher than the supply, and the discharge end (the longer leg) is lower than the supply.

Steam Siphon.—A siphon in which a partial vacuum is made and maintained by the condensation of steam.

Siphon Condenser.—See "Condenser."

Siphon Culvert.—Same as "Siphon," *q.v.*

Sisal Hemp.—See "Hemp."

Sisal Rope.—See "Rope."

Sister Block.—See "Block."

Sister Hook.—See "Hook."

Skeleton-construction.—A framework of structural steel which sustains all the external loads or forces from the top of a building to the foundation.

Skeleton Diagram.—See "Diagram."

Skeleton Drawing.—Same as "Skeleton Diagram," *q.v.*

Skelp.—A strip of iron or steel prepared for making pipes and tubes.

Skew.—Making an oblique angle.

Skew Arch.—Same as "Oblique Arch." See "Arch."

Skewback.—The beveled stone, iron plate, or course of masonry which supports the foot of an arch ring. Also the casting on the end of a trussed girder to which the tension rod is attached.

Skew Bridge.—See "Bridge."

Skew Crossing.—Same as "Oblique Crossing." See "Crossing."

Skew Portal.—See "Portal."

Skew Span.—See "Span."

Skid.—To slip or slide without revolving.

Skid Girder.—See "Girder."

Skids.—Timbers used as a track in sliding heavy objects.

Skid-way.—A frame or form used for skidding heavy articles.

Skim-coat.—A finishing coat of plaster used to give a smooth surface to a rough wall of concrete.

Skimming Plate.—See "Plate."

Skin.—A thin coating formed during the cooling of cast metals.

Skin Friction.—See "Friction."

Skinned Bolt.—See "Bolt."

Slab.—A flat, relatively thin, mass of wood, stone, concrete, or metal.

Bending Slab.—A plate of metal with holes punched in it for holding pins around which thin plates or bars may be bent to required shape.

Slabbed Tie.—See "Tie."

Slab Tie.—See "Tie."

Slack.—Not tightened; that portion required to be taken up to make a structure rigid. To loosen.

Slag.—Cinder. The molten substance, other than the metal under treatment, consisting of acid or basic oxides which may be composed of the gangue of the ore combined with a flux (usually lime) in smelting operations; or of substances (usually lime and iron oxide) introduced for the purpose of effecting or assisting in the purification process.

Slag Cement.—See "Cement."

Slag Concrete.—See "Concrete."

Slag Sand.—Slag ground to the consistency of sand and used to replace the sand in mortar or concrete.

Slake.—To become disintegrated by the action of water or moisture.

Slaked Lime.—See "Lime."

Slaking.—The action of the air or water in producing disintegration.

Air Slaking.—Decomposition of any material exposed to the air, such as lime.

Slapped Cement.—See "Cement."

Sledge.—A heavy hand hammer having a long handle for use by both hands.

Sledge Hammer.—See "Hammer."

Sleeper.—A railroad cross tie of wood, concrete, or metal, used to support and fix the rails of a railroad track. Generally called a "Tie."

Sleeve.—A hollow cylinder or tube, used to connect round bars, bolts, shafting, etc.

Handle Lock Sleeve.—A threaded sleeve, or elongated nut, having a handle by which it is turned and locked at some desired position.

Lock Sleeve.—A sleeve connecting two parts of shafting and arranged to lock with one of them by means of a shifting motion.

Sleeve Coupling.—See "Coupling."

Sleeve Nut.—See "Nut."

Slide, or Land Slide.—A displacement of an unstable earth bank due to gravity and saturation.

Slide Rule.—An instrument for making rapid computations mechanically, consisting of two or more sliding or revolving parts bearing graduations based on the logarithms of the numbers shown.

Duplex Slide Rule.—A slide rule of the stick type having an interior slide of the same thickness as the rule and its two faces flush with those of the exterior portions. Both rule and slide are graduated on both faces.

Manheim Slide Rule.—A slide rule of the stick type graduated on one face only. The slide has one face only flush with the rule though graduated on both faces; being thinner than the rule, it has to be reversed when using the lower face.

Spiral Slide Rule.—A slide rule of the revolving type. It consists of a hollow sleeve having graduations and being capable of sliding along and revolving around a continuous cylinder which is held stationary by a handle. The scale on the sleeve is arranged in the form of a spiral, hence the name.

Thacher Slide Rule.—A slide rule of the revolving type having an exterior frame of twenty graduated bars attached to rings at their ends. The slide is an interior cylinder and is capable of both rotation and sliding inside the bars. The exterior frame of bars is also capable of rotation. A most valuable instrument in any bridge engineer's office.

Slide Valve.—See "Valve."

Sliding Bearing.—See "Bearing."

Sliding-ends.—The ends of a bridge resting on a sliding bearing.

Sliding Friction.—See "Friction.'

Sliding Pulley.—See "Pulley."

Sling.—A closed loop of wire, chain, or rope for convenient passing under a body and attaching to the hook of a derrick tackle for the purpose of hoisting.

Rope Sling.—A sling made of rope.

g.—See "Dog."

An earth slide. A long, narrow water space between two wharves or piers.

Slip.—Same as "Land Slide," *q.v.*

int.—See "Joint."

g Chisel.—See "Chisel."

g Hammer.—See "Hammer."

rick.—See "Brick."

—The inclined face of a cutting or of an embankment.

Stake.—See "Stake."

Wall.—See "Wall."

—An oblong hole cut through a piece of metal, plank, etc. A groove cut in an xle or shaft to receive the key of a pulley or gear.

d Eye.—See "Eye."

ing.—The act of cutting a slot.

g-machine.—A machine for cutting slots.

Washer.—See "Washer."

etting Cement.—See "Cement."

e.—An artificial channel for conducting water. To wash away earth or gravel by means of a swift stream of water.

y.—Consisting of light gravel and silt.

Ashlar.—See "Ashlar."

Ashlar Masonry.—See "Masonry."

lt.—To extract the metals from an ore by heating in a reduction furnace, usually by means of coal, coke, or charcoal.

h's (C. Shaler) Formula.—A formula for long timber columns, viz.:

$$p = \frac{5000}{1 + \frac{1}{250} \cdot \frac{l^2}{d^2}}$$

where p = ultimate compressive resistance in pounds per square inch.
l = length of column in inches.
d = least side of column section in inches.

oth Dressing.—See "Dressing."

oth Fracture.—See "Fracture."

g.—A tree, or portion thereof, having one end resting on the bed of a river or lake and the other end at or near the surface of the water.

ke.—To drag or haul, especially by a chain or rope fastened to one end of an object such as a log. A defect in rolled metal.

p.—A tool used in field riveting to form the head of the rivet. It consists of a hammer-like head on a handle and having one of its faces hollowed out to give the desired shape to the rivet head. By placing this on the hot metal and striking it with a sledge, the rivet end is forced to conform to the shape of the hollow. Also a spring catch as in a snap-hook. To break suddenly with a short fracture.

Rivet Snap.—A tool used for forming the head of a rivet. See "Snap."

p-head Rivet.—See "Rivet."

Link.—See "Link."

ch Block.—See "Block."

tch Block Sheave.—See "Sheave."

pping.—Chipping off, as with a tool struck by a hammer. Cutting off quickly with a pair of snips.

—Small, stout hand shears used for cutting sheet metal.

b.—To check suddenly as in the case of a swiftly moving rope by taking a turn around a post or tree.

bbing Line.—See "Line."

[illegible]

[illegible] of some [illegible]

[illegible] Drill.—See "Drill." [illegible]

[illegible] Hoe.—See "Hoe."

[illegible] Wrench.—See "Wrench."

[illegible]—The lower surface of an [illegible]

[illegible] Steel.—See "Steel."

[illegible] Wood.—See "Wood."

Solder.—A compound of different [illegible] melted is used to unite pieces of [illegible] or sheet tin.

Soldering Iron.—A tool with a pointed or [illegible] an iron shank and a wooden handle, [illegible]

Soldering Pot.—A small, portable furnace [illegible] soldered together and a pot to hold the [illegible]

Solder Joint.—See "Joint."

Solenoid.—An electrical conductor wound in [illegible] axis.

When carrying an electric current it acts [illegible]

Solenoid Brake.—See "Brake."

Sole Plate.—See "Plate."

Solid Arch.—See "Arch."

Solid Steel Floor.—See "Floor."

Solid Web.—See "Web."

Solitary Bent.—See "Bent."

Solvent.—A fluid, such as water or alcohol, [illegible]

Sounding.—Measuring the depth of water. Also [illegible] surface, of bed rock or other strata.

Sounding Rod.—See "Rod."

Sound Knot.—See "Knot."

Soundness of Cement.—See "Cement."

Spacer.—An iron casting usually spool-shaped with [illegible] to separate beams or girders when two or more [illegible] member.

Spacing Punch.—See "Punch."

Spacing-table.—A movable table with a gauge on one [illegible] punching work.

Spacing Washer.—Same as "Packing Washer." See "W[illegible]

Spade (in concreting).—To work the mortar to the face [illegible] spade up and down next to the form. A digging tool [illegible]

Spall or Spawl.—A small piece of stone chipped from a larg[illegible]

Spalling Hammer.—See "Hammer."

Span.—The distance between two supports holding up a [illegible] that rests on the supports, as a span of a bridge. To [illegible] another by means of a structure.

Anchor Span.—In a bridge consisting of a series of cant[illegible] ates two cantilever arms of other spans is termed an [illegible]

Bascule Span.—The moving span of a bascule bridge, q.[illegible]

Beam Span.—A span built with beams.

Span.

Cantilever Span.—That span of a cantilever bridge, which contains a suspended span and either one or two cantilever arms. In some cases the suspended span (most improperly) is omitted, making the cantilever span consist of two cantilever arms only.

Channel Span.—The span which bridges the deepest part of a river or that part most accessible for navigation.

Clear Span.—The distances between the two inside faces of the supports of a span.

Continuous Span.—A span that is supported on more than two piers or on more than one abutment and one pier and which distributes the load to the various supports on which it rests, or a series of consecutive spans effectively connected together over the points of support.

Deck Span.—One of the spans of a "Deck Bridge," *q.v.*

Draw Span.—A movable span in a bridge over a navigable stream, to permit the passage of vessels.

Effective Span.—The distance from centre to centre of end pins in a bridge span, or that between centres of bearings in any structure.

Fixed Span.—A span that is not movable, in contradistinction to a draw span.

Girder Span.—A span built of girders.

Half-through Span.—A span in which the deck is placed between the upper and the lower chords and where there is no overhead bracing.

Intermediate Span.—Any one of the spans between the end spans of a bridge.

Lift Span.—A span of a bridge that is raised for the passage of vessels.

Movable Span.—Any span of a bridge that may be moved in any manner to allow passage for vessels through or under the bridge.

Shore Span.—Either the first or the last span of a bridge.

Simple Span.—A span that rests on two supports, one at each end, and that does not affect the stresses in the adjoining spans.

Skew Span.—A span making an angle, other than a right angle, with the axes of the piers and abutments.

Spread Span.—A span at the end of a bridge so spread out at the shore that diverging tracks may be run thereon.

Suspended Span.—A span connecting two cantilever arms and supported wholly thereby.

Swing Span.—A span that revolves on a centre pier or swings from an end pier to allow a passage for vessels through the bridge.

Through Span.—A span in which the traffic is carried between the trusses and which has lateral bracing in the plane of the upper chords.

Tower Span.—A span directly over and supported by a tower in a trestle or viaduct.

Truss Span.—A span supported by trusses.

Span Dog.—See "Dog."

Spandrel.—The space from abutment to abutment in an arch bridge extending from the top of the arch masonry to the top of the roadway.

Spandrel Braced.—In the form of a trussed arch, in which the top chord is horizontal and the bottom chord is arched.

Spandrel Column.—See "Column."

Spandrel Hanger.—See "Hanger."

Spandrel Wall.—See "Wall."

Spanish Windlass.—See "Windlass."

Span-length.—The distance from centre to centre of supports.

Clear Span Length.—Same as "Clear Span." See "Span."

Effective Span Length.—Same as "Effective Span." See "Span."

Spanner.—A wrench for coupling and uncoupling hose.

Sparry.—Pertaining to the carbonate of iron.

[illegible]

Specific Gravity.—See "Gravity." [illegible]

[illegible] [illegible]—See "Test." [illegible]

[illegible]—Having a [illegible] and also a variety of pig iron [illegible]

[illegible]—[illegible]

Spider.—A low tripod; the [illegible] wheel may be bolted, [illegible] rollers to the central [illegible]

Spider-rod.—Same as "Radial [illegible]

Spiegeleisen.—Pig iron that [illegible]

Spike.—A large nail or pin [illegible]

Barge Spike.—A long, slim, [illegible]

Boat Spike.—A square, chisel-pointed [illegible] eight to ten inches long, used to [illegible] crossings, etc.

Button-head Spike.—Similar to "[illegible]

Cut Spike.—A spike cut or stamped [illegible]

Floor Spike.—Any spike used in putting [illegible]

Hand Spike.—A wooden lever for turning [illegible]

Jag Spike.—Same as "Jag Bolt." See "Bolt." [illegible]

Marline Spike.—A tapering, sharp-pointed, [illegible] of a rope for splicing.

Nail-head Spike.—A spike having a long, [illegible]

Railroad Spike.—Same as "Track Spike," *q.v.*

Screw Track-spike.—A large, threaded, [illegible] out on the underside. These screw spikes are [illegible] spike, especially on bridges. A hole is first [illegible] then the spike is screwed into place.

Spike Knot.—See "Knot."

Spike Maul.—See "Maul."

Spile.—Incorrectly used for "Pile," *q.v.*

Spindle.—A short shaft carrying a wheel. A vertical [illegible] "Baluster," *q.v.*

Spin Gear.—See "Gear."

Spiral.—The curved path of a moving point rotating [illegible] radius.

Spiral Curve.—Same as "Easement Curve." See "Curve." [illegible]

Spiral Gear.—See "Gear."

Spiral Riveted Pipe.—See "Pipe."

piral Slide Rule.—See "Slide Rule."

irit Level.—See "Level."

lasher.—A guard placed over a wheel to prevent oil [illegible] on persons or neighboring objects.

lay.—To widen or spread out as in the wing walls of [illegible]

lice.—To unite two pieces firmly together. The parts [illegible]

Butt Splice.—A splice formed by bringing the dressed [illegible] material together and joining them by welding or [illegible] or scabs.

le Splice.—A joint or connection made of two ends of a cable. The weaving together of the ends of two ropes or cables.

rd Splice.—A splice made in a chord of a truss.

e Splice.—A splice formed by bending back the end of a rope or cable and weaving it into the body of the rope so as to form a loop, or an eye.

nge Splice.—A splice made in the flange of a beam or girder.

l Splice.—A splice capable of developing the full strength of a member.

Splice.—A splice made by placing one piece on top of another and fastening together with pins, nails, screws, bolts, rivets, or similar contrivances.

rtial Splice.—A splice that is capable of developing only a part of the resistance of a member.

e Splice.—The joining of two piles, end on end, by means of wooden scabs or iron plates bolted to them or by means of a cylindrical steel shell slipped over and bolted to the ends.

l Splice.—The joining of two rails by splice bars and bolts.

ngle Splice.—In a member composed of a number of component parts, such as one with compound web plates, a shingle splice consists in cutting all of the said component parts at different but near-by locations and letting the splice plates extend over all the individual joints.

oppered Splice.—A short piece of rope spliced into a longer rope to form a stopper or check to prevent the rope from running out of a block.

tal Splice.—Same as "Full Splice," *q.v.*

eb Splice.—A splice joining two web plates.

ce Bar.—See "Bar."

ced Pile.—See "Pile."

e Joint.—See "Joint."

ce Plate.—See "Plate."

ing Shackle.—See "Shackle."

e.—A thin wooden strip or filler for inserting in cracks between planks.

Gear.—See "Gear."

Pulley.—See "Pulley."

s.—Short, flat strips of steel.

t Switch.—See "Switch."

t Tie.—See "Tie."

ke Wheel.—See "Wheel."

nge.—Metal in a porous form.

giness.—The state or character of being soft, porous, or spongy.

ol.—A short cylinder with a longitudinal hole through its centre; also a nigger-head on a hoisting engine.

on.—A small bowl-shaped piece of metal with a rod for a handle used to clean out inaccessible holes such as a drill hole.

ut.—Same as "Chute," *q.v.*

ead.—To flatten out; to widen.

eader.—A tool for spreading refractory metal over a furnace bottom.

ead Foundation.—See "Foundation."

eading-rate.—The rate a paint or paint material as used is brushed out to a continuous uniform film, measured by the area which a unit volume will cover.

ead Span.—See "Span."

ng.—An elastic body used to reduce the force of impact. To rise or move quickly. A flow of water from the ground.

alance.—See "Balance."

Clips.—See "Clips."

Dolly.—See "Dolly."

[illegible]

[illegible] Pile.—Same as "Batter P

[illegible]

[illegible] Wheel.—Same as "Gear,"

Square.—A four-sided, plane,
to the two adjacent. A tool
laying out a right angle.

Square Thread.—See "Thread."

Square-threaded Screw.—See "Screw."

Squeegee.—A wooden scraper having a
grout in constructing brick pavements.

Stability.—The ability to resist change

Moment of Stability.—The resistant
with a lever arm equal to the distance
of the structure about which it tends to

Stable.—Standing firmly in place.

Stadia.—A method of measuring distances by
made by the stadia wires in the telescope of a

Stadia Rod.—See "Rod."

Stadia-wires.—Two horizontal wires placed
the telescope of a transit.

Stage.—A platform, either fixed or swinging, used
scaffold; also the interval between two platforms
lifting excavated material.

Stagger.—To arrange in a zigzag order, as the staggering

Staggered Riveting.—See "Riveting."

Staging.—Same as "Stage," used collectively. See

Stainer.—One who applies stain. A coloring matter.

Stake.—A short, flat-sided piece of wood sharpened at
on the surface of the ground where work is to be

Berme Stakes.—Stakes showing the side lines of a

Finishing Stakes.—Final stakes set for the completion

Grade Stakes.—Stakes showing by suitable notation the
the grade line.

Slope Stakes.—Slope stakes or toe stakes are stakes
cut or fill in order to indicate the position of the top

Stalk.—A spiked iron rod forming the centre for a core;
of a ladder.

Stamp.—A die; to make an impression on a surface by

Stamping Hammer.—See "Hammer."

Stanchion.—An upright post supporting a roof.

Standard.—Any measure of extent, quantity, quality,
by general usage.

Standard Gauge.—See "Gauge."

Standardize.—To regulate by a standard.

Standardized Tape.—See "Tape."

Standard Knot.—See "Knot."

Standard Sieve.—See "Sieve."

Standard Thread.—See "Thread."

Standing Block.—A pulley-block fixed to some permanent support.

Standing Bolt.—Same as a "Stud Bolt." See "Bolt."

Standing-end.—As applied to a rope, it is the end made fast to a block or other fixed point.

Standing Pile.—See "Pile."

Standing Rope.—See "Rope."

Staple.—A standard; a piece of wire or metal bent into the shape of the letter U, and having its ends sharpened to a point so as readily to penetrate wood.

Starling.—A cutwater; the projecting end of a bridge-pier, usually so shaped as to allow ice, drift, etc., to strike it without injury.

Starling Coping.—Same as "Cocked-hat," *q.v.*

Starred Angles.—See "Angle."

Star Section.—See "Section."

Star Strut.—See "Strut."

Static.—Pertaining to or designating bodies at rest or forces in equilibrium.

Static Deflection.—See "Deflection."

Static Equilibrium.—See "Equilibrium."

Static Load.—See "Load."

Statics.—That branch of mechanics which deals with a balanced system of forces acting on bodies at rest.

Graphic Statics.—A method of resolving and combining forces, determining their resultant, its direction and point of application, shears, and bending moments by graphical processes.

Static Stress.—See "Stress."

Stationary Engine.—See "Engine."

Stave.—One of the boards joined laterally to form a barrel or hollow cylinder. Pieces of wrought iron welded together as a basis for making shafts. To swell up the end of a tube.

Stay.—A rope used to support a vertical pole or mast, such as a derrick mast. To support by means of stays.

Back-stay.—A rope or cable extending backward from the head of a mast and fastened to some permanent object. A rear cable in a suspension bridge running from the top of tower to the anchorage.

Stay Bolt.—See "Bolt."

Stayed-link Chain.—See "Chain."

Stay Plate.—Same as "Batten Plate." See "Plate."

Stay Pile.—See "Pile."

Stay Rod.—See "Rod."

Stay Wire.—Same as "Guy Wire," *q.v.*

Steamboat Jack.—See "Jack."

Steamboat Ratchet.—See "Ratchet."

Steam-chest.—The chamber, adjoining the cylinder of a steam engine, in which the slide valve works.

Steam Condenser.—See "Condenser."

Steam Crane.—See "Crane."

Steam-cylinder.—A cylinder in which steam does work by expanding against a movable piston.

Steam Dredge.—See "Dredge."

Steam Engine.—See "Engine."

Steam Gauge.—See "Gauge."

Steam Hammer.—See " Hammer."

Steam Hammer Pile Driver.—See " Pile Driver."

Steam Hoist.—See "Hoist."

Steam Hose.—See "Hose."

Steam Jacket.—See "Jacket."

Steam Jet.—See "Jet."

Steam Port.—See "Port."

Steam Riveter.—See "Riveter."

Steam Siphon.—See "Siphon."

Steatite.—Massive talc or soapstone, a hydrous magnesian silicate.

Steel.—A modified form of iron, not occurring in nature, made from pig iron by oxidizing most of the carbon.

Acid Steel.—Steel made without the use of lime.

Acid Bessemer Steel.—A metal produced by the decarburization of crude pig iron in a converter where finely divided air currents are blown through the molten mass. The lining of the converter is of a silicious material that will have no effect on the phosphorus, hence that element is not eliminated.

Acid Open-hearth Steel.—A metal formed of pig iron, cast iron, and wrought iron or steel scrap, which is converted into steel by the direct action of an oxidizing flame in a regenerative gas furnace. The furnace is lined with a silicious material that has no effect on the phosphorus content.

Alloy Steel.—A steel carrying a certain portion of some other metal, such as nickel or vanadium.

Basic Open-hearth Steel.—A metal formed of pig iron, cast iron, and wrought iron or steel scrap, which is converted into steel in a furnace having a lining of dolomitic limestone in order to resist the action of the slag. This slag contains much of the phosphorus in combination with calcined lime with which the furnace is charged. In this way the phosphorus content is reduced materially.

Bessemer Steel.—Steel made by the "Bessemer Process," *q.v.*

Blister Steel.—Steel made from wrought iron by heating it while in contact with some form of carbon.

Boiler Steel.—A medium steel rolled into plates from one-fourth to one-half inch in thickness and used for making boilers.

Bronze Steel.—An alloy of copper, tin, and iron used as gun metal.

Burning Steel.—A mechanical separation of the grains due to extreme overheating of steel.

Burnt Steel.—Steel that has been overheated in the making or remelting. It is coarse-grained and very brittle when either hot or cold.

Carbon Steel.—Ordinary steel which contains no other alloying element than the usual amount of manganese. The term is generally employed in contradistinction to nickel steel or other alloy steel.

Case-hardened Steel.—Steel with the outer skin hardened by heating, after being made into shape, with some such animal substance as grease, bone, hoofs, or horns.

Case Steel.—The outside skin on steel caused by case hardening.

Cast Steel.—Steel that is cast into shape directly from the furnace instead of being cast into ingots and rolled or melted.

Cemented Steel.—Steel produced by impregnating bars of wrought iron or soft steel with carbon at a temperature below the melting point.

Charcoal Steel.—Steel in which charcoal is used for a fuel in its production.

Chrome Steel.—Steel that usually contains two per cent of chromium and from eight-tenths of one per cent to two per cent of carbon. It is very hard and has a high elastic limit.

short Steel.—A steel that is very brittle when cold, usually due to an excess phosphorus.

verted Steel.—Steel that has undergone a process of cementation in fire brick ambers or converting pots.

ble Cast Steel, or Crucible Steel.—Steel made by melting down in a closed ucible the various grades of iron or steel with or without the addition of carbon, e, or other materials.

le Shear Steel.—Steel made by a process in which the shearing and welding scribed for single shear steel is repeated.

Steel.—Burnt steel showing very coarse, bright grains when fractured.

Steel.—Flemish steel wrought from wedge-shaped ingots.

an Steel.—Steel made in Germany—an obsolete term.

ning of Steel.—Bringing the metal to the condition in which it is best able resist abrasion or scratching. This is accomplished by heating the steel to a h temperature and cooling quickly, or by mechanical working.

Steel.—Steel that has undergone the process of hardening. Also same as igh Steel," *q.v.*

Steel.—Steel made by a process patented by a Mr. Hay. It was used in the struction of the bridge over the Missouri River at Glasgow, Mo. It is no longer ufactured.

Steel.—Steel containing a comparatively large amount of carbon, from one- to one per cent.

geneous Steel.—A steel solid and free from blow holes. A variety of crucible l easily bent and worked.

hort Steel.—A steel that is very brittle when hot—usually due to an excessive ount of sulphur.

Steel.—Steel run from the furnace into rectangular moulds to be subsequently lled or forged.

Steel.—A soft steel containing a small amount of carbon—less than one-fourth one per cent.

ganese Steel.—Steel containing from eleven per cent to fourteen per cent of nganese and one and one-half per cent of carbon. This is a very hard, brittle eel and has to be treated by cooling in water to remove the extreme brittleness. sed where high resistance to abrasion is necessary. Mayarí Steel, see page 68.

um Steel.—Steel neither very hard nor very soft, containing from one-fourth one-half per cent of carbon.

Steel.—A soft steel. Same as "Low Steel," *q.v.*

et Steel.—A steel containing one and one-half per cent of carbon and from e to eight per cent of tungsten, which when hardened by air cooling holds its per until it becomes red-hot.

l Steel.—Steel containing from three per cent to five per cent of nickel and n two-tenths to one-half per cent of carbon. The addition of the nickel increases strength and the elastic limit of the metal.

-hearth Steel.—Steel produced in a regenerative, reverberatory furnace where hearth is open and exposed to the action of the flame.

Steel.—A defect in the top of an ingot due to the shrinking of metal while ing, thus leaving a cavity.

Steel.—A steel made by the puddling process in a reverberatory furnace in ch the carbon is reduced at a low temperature to one-half of one per cent. This is seldom used nowadays.

Steel.—Treating burnt steel by heating and mechanically working the

—A soft steel from which rivets are made.

[illegible]

treatment of cooling [illegible]

Tool Steel.—Steel which, by [illegible] metals, is adapted to [illegible] so as to permit of high [illegible] lowing as the best composition [illegible] 18.19 per cent; chromium, [illegible] per cent; and silicon, [illegible] per cent.

Tungsten Steel.—Steel usually [illegible] (sometimes as much as twenty-[illegible] of carbon.

Vanadium Steel.—An alloy steel [illegible] has the effect of raising the elastic [illegible] by purification.

Weld Steel.—Steel capable of being welded.

Wild Steel.—Steel that spits and flies in the [illegible] of the metal.

Steel Joist.—See "Joist."

Steel Pile.—See "Pile."

Steel Press.—See "Press."

Steining.—The brick or stone wall lining a vault.

Stem.—The handle of a tool; the projecting rod [illegible] of an object connecting two larger portions.

Stem-section.—That portion of an object containing [illegible]

Stepped.—Formed into a series of steps.

Stepped Gear.—See "Gear."

Step Stone.—See "Stone."

Stereotomy.—The science of cutting solids into certain [illegible] stonework.

Sterro Metal.—See "Metal."

Stevedores' Knot.—See "Knot."

Stiff.—Rigid, not easily bent, not working easily.

Stiffener.—A secondary member, usually an angle, [illegible] buckling.

End Stiffener.—Vertical angles riveted to the web of [illegible] purpose of stiffening it and transferring the end [illegible]

Intermediate Stiffener.—Any one of the stiffeners [illegible] end stiffeners.

Web Stiffener.—An angle riveted to the web of a [illegible] prevent buckling.

Stiffening Angles.—See "Angle."

Stiffening Girder.—See "Girder."

Stiffening Rib.—See "Rib."

Stiffening Strut.—See "Strut."

Truss.—See "Truss."

—See "Leg."

Derrick.—See "Derrick."

—In reinforced concrete beams or slabs, a U-shaped bar inserted for the purpose esisting diagonal tension, or so-called shear.

ivet.—See "Rivet."

—The raw material used for charging a furnace. The foundation for the anvil a power hammer. An apparatus or tool for holding another tool.

Stock.—The frame, with handles attached, used for holding and turning the s which cut the threads on rods or pipes.

Stock.—The holder which receives the shank of a drill.

Stock.—Same as "Die Stock," *q.v.*

amming.—A process for stopping leaks in a cofferdam by ramming clay through le cut in the supporting timbers.

—A small piece of rock. A piece of rock hewn or shaped for specific use.

Stone.—Same as "Voussoir," *q.v.*

Stone.—Stone roughly dressed with a heavy, axe-like tool.

tone.—One of the stones in a bottom course of masonry.

Stone.—A flat stone bridging a gutter or other small opening.

Stone.—A term applied to rock which is crushed or broken into small pieces used for concrete, road pavement, ballast for tracks, etc.

Stone.—Any rock having the necessary alumina, silica, and lime content ich can be converted into cement under proper treatment.

tone.—Stone which has been dressed with a mason's chisel to a smooth surface.

mension Stone.—Large cut stone having the face left rough, used in massive asonry.

chester Sandstone.—A sandstone found in Dorchester, New Brunswick.

fted Stone.—Stone having a narrow chisel-draft cut around the face or margin.

Stone.—A moulding or cornice projecting from a column to prevent rain water rom trickling down.

Stone.—An oxide of iron rendered impure through the admixture of silica and lay.

ystone.—The centre or highest voussoir or arch stone.

sonry Stone.—Stone employed in masonry construction.

man Stone.—A rough classification for stone of a size that can be lifted and laced by one man.

Stone.—Same as "Voussoir," *q.v.*

bed Stone.—Same as "Rubbed Dressing," *q.v.*

dstone.—A rock formed by the consolidation of sand.

nging Stone.—The first course of stone below the springing line in an arch.

Stone.—The stone which forms a step in foundations.

Axe.—See "Axe."

oat.—A boat or barge which carries stones.

rusher.—A machine for crushing stones.

ridge.—See "Bridge."

utter.—See "Cutter."

rill.—See "Drill."

irder.—See "Girder."

ammer.—See "Hammer."

laner.—A machine for smoothing the surface of a flat stone.

olisher.—Either a machine or a man that polishes the face of a stone, after it been smoothed, by the use of powdered pumice-stone and water.

—Same as "Belt Course," *q.v.*

aw.—See "Saw."

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] Cable.—See "Cable.

[illegible] Bolt.—See "Bolt."

Straight Abutment.—See "Abutment

Straight Dolly.—See "Dolly."

Straight-edge.—A thin bar of wood
lines. Also a bar or narrow
construction work to obtain a

Straightening-machine.—A machine

Straightening Rolls.—See "Rolls."

Straight Line.—See "Line."

Straight-line Formula.—See "Formula."

Straight-link Chain.—See "Chain."

Straight-shank Drill.—See "Drill."

Strain.—The deformation caused by an
or to any bridge member. Often

Angular Strain.—Same as "Torsional

Compressive Strain.—The deformation
"Shortening."

Crushing Strain.—An incorrect but
strength in compression. See "Ultimate

Lateral Strain.—A deformation at right

Rate of Strain.—The ratio of the

Shearing Strain.—The deformation produced

Tensile Strain.—The deformation produced
"Stretch" or "Elongation."

Torsional Strain.—A deformation in a

Transverse Strain.—A deformation caused by
axis of a member.

Strainer.—Any device used to separate small
strainer on the end of a suction hose of a

Strain Sheet.—Wrongly used for "Stress Sheet," q.v.

Strake.—A breadth of planking; the hoop or tire

Strength.—The capacity to resist distortion or

Compressive Strength.—The capacity to resist

Crushing Strength.—The ultimate power of a
crushing.

Hydraulic Strength.—The strength developed by
in water.

Proof Strength.—The greatest resistance that a
without the stress exceeding the elastic limit of

Shearing Strength.—The resistance which a body

Tensile Strength.—The resistance which a body can

Strand.—One of the small threads used in making rope

Strap.—A narrow band of flexible material used to
articles.

Butt Strap.—A steel attaching plate, used in
outside of two abutting timbers.

Eccentric Strap.—The band of iron or steel which
the eccentric and in which it revolves.

Strap Bolt.—Same as "Lug Bolt," *q.v.*

Strap Hinge.—See "Hinge."

Strap Joint.—See "Joint."

Strap Rail.—See "Rail."

Stratification.—A geological formation consisting of layers or bands

Stratum.—A natural or artificial bed of rock or earth.

Straw-boss.—Same as "Pusher," *q.v.*

Stress.—An internal distributed force that resists the change in shape and size of a body subjected to external forces.

Advancing Load Stress.—A stress in a member induced by a load advancing on the structure.

Allowable Unit Stress.—The allowable stress per unit of area given in the specifications.

Apparent Stress.—A term used to indicate that the stress has been determined by the principles of statics, and, therefore, ignoring the effect of the lateral deformation of the member or that of secondary stresses.

Axial Stress.—A stress, either tension or compression, acting along and in the direction of the axis.

Balanced Load Stress.—A stress in a member of a draw span induced by having both arms of the draw symmetrically loaded.

Bearing Stress.—The stress developed in a bearing by the superimposed load.

Bending Stress.—The stress produced in a member by a bending moment.

Bond Stress.—The longitudinal stress set up between the surface of a reinforcing bar and the surrounding concrete.

Breaking Stress.—The stress developed in a member at the point of rupture.

Buckling Stress.—A compressive stress so great that the elastic limit of the piece is exceeded, and, in consequence, a buckling or bulging of the material occurs.

Centre of Stress.—The point of application of the resultant of the stresses on a section.

Centrifugal Stress.—A stress due to the centrifugal reaction of a live load moving in a curve: Any stress acting in an outward direction from the centre of a body.

Centripetal Stress.—Any stress acting toward the centre of a body.

Chord Stress.—Any stress which exists in a chord of a truss.

Combined Stress, or **Compound Stress.**—A union of stresses such as direct stress and bending.

Compressive Stress.—A stress which resists the shortening effect of an external compressive force.

Concentrated Load Stress.—Stress induced in a member by concentrated loads on a structure.

Conjugate Stresses.—Two sets of stresses each of which acts parallel to the plane upon which the other acts.

Counter Stress.—A stress in the web member of a truss which occurs for certain positions of the live load and is the reverse of the usual stress in the member or panel.

Crippling Stress.—The stress resulting in a member at the point of crippling. The stress necessary to cripple the member.

Cumulative Stress.—A stress that piles up in a member.

Dead Load Stress.—The stress resulting from the application of a static load. Generally means the stress produced in a structure by its own weight.

Direct Stress.—A stress resulting from a direct application of the load.

Direct Wind-load Stress.—Stress due to the wind load applied directly to the lateral trusses of a span.

Ellipse of Stress.—A relation between stresses such that if a pair of principal stresses, of the same or opposite kinds, be represented by the semi-major and semi-minor axes of an ellipse, respectively, the intensity of the stress in any direction in the same plane is represented by the semi-diameter of the ellipse in that direction.

[illegible]

[illegible]

[illegible]

[illegible] **Wind Stress.**—[illegible]

Induced Stress.—Same as "[illegible]

Initial Stress.—Stress put on [illegible] is accomplished by making the [illegible] normal length and then forcing [illegible] turnbuckle after erection.

Intensity of Stress.—The stress per [illegible]

Internal Stress.—Any stress in a [illegible]

Lateral Stress.—A stress which acts at [illegible] which tension or compression is pro[illegible] stress in a member of a lateral system.

Live Load Stress.—Any stress caused by [illegible]

Longitudinal Stress.—Stress parallel to the [illegible]

Main Stress.—Same as "Direct Stress," [illegible]

Maximum Stress.—The greatest stress that [illegible] greatest stress a member can have with [illegible]

Normal Stress.—A stress which acts at right [illegible] body.

Primary Stress.—Same as "Main Stress," [illegible]

Principal Stresses.—Conjugate stresses that are [illegible]

Pure Stress.—A term used for cases where only [illegible]

Range of Stress.—The limits between which the [illegible] as the load changes.

Repeated Stress.—A stress due to a load which [illegible] body a great number of times.

Resultant Stress.—The stress resulting from [illegible] a piece simultaneously.

Reversal of Stress.—The changing of stress from [illegible] versa.

Stress.

Torsional Stress.—The stress arising from the deformation set up by a torque or twisting moment.

Total Stress.—The sum of all the stresses at a section of a body.

Traction Stress.—A stress caused by the thrust of a braked train due to the friction of the wheels on the rails when skidding, or by the horizontal effort of the locomotive wheels against the rails.

Transferred Load Stress.—The stress in a member caused by the transferring of a load from another member.

Transverse Stress.—A stress at right angles to the axis of a member.

True Stress.—A stress as measured by the deformation as it actually occurs.

Ultimate Stress.—The greatest stress which can be produced in a body before rupture occurs.

Uniform Stress.—A stress which has a uniform intensity throughout its area of action.

Uniform Load Stress.—A stress resulting from the application of a load uniformly distributed over the structure.

Uniformly Varying Stress.—A stress, the intensity of which varies as its distance from a fixed point.

Unit Stress.—The stress per unit of area; the measure of intensity of stress.

Uplift Stress.—A stress due to an uplift action, as that from the end lifting machinery in a swing span.

Vibratory Stress.—A stress caused by vibration.

Web Stress.—Any stress in a web member of a truss.

Wind Stress.—A stress caused by the application of a wind load to the structure.

Working Stress.—The allowable stress on any piece as provided in the specifications. Carelessly used for "Working Unit Stress," *q.v.*

Working Unit Stress.—The allowable unit stress or intensity on any piece as provided in the specifications.

Stress Couple.—See "Couple."

Stress Diagram.—See "Diagram."

Stress Sheet.—Same as "Stress Diagram." See "Diagram."

Stretcher.—In masonry, a stone laid with its long dimension parallel to the wall.

Stretcher Course.—See "Course."

Strict-heart Tie.—See "Tie."

Striking.—Hitting with a hammer or sledge, as striking a drill. Removing camber blocks or arch forms.

Striking Hammer.—See "Hammer."

Striking of an Arch.—See "Arch."

Striking Wedge.—See "Wedge."

String Course.—See "Course."

Stringer.—A longitudinal member extending from panel to panel of a bridge and supporting the ties or the flooring.

Chord Stringer.—A chord length subjected to bending as well as to direct stress.

Continuous Stringer.—A stringer that extends over two or more panels.

Jack Stringer, or Outside Stringer.—A stringer placed outside the line of main stringers.

Track Stringer.—A beam or girder carrying a track.

Stringer Bolt.—See "Bolt."

Stringer Bracing.—See "Bracing."

Stringer Packing.—See "Packing."

Stringer-spacing.—The distance between the centres of stringers and their location with reference to the centre line of structure.

String Packing.—See "Packing."

String-pieces.—The sloping beams of a stairway which support the treads.

String Polygon.—Same as "Equilibrium Polygon," *q.v.*

[illegible]

[illegible].—A narrow [illegible]
[illegible] to overcome the [illegible]

Stripped Threading.—See [illegible]

Stripping.—Removing forms

[illegible].—A local term for

Stroked.—A form of masonry

Columnar Stroked.—A form of dressing

Fibrous Stroked.—A form of dressing

Structure.—A general term for anything
building. The arrangement and

Granular Structure.—A granular
caused by overheating in the

Lamellar Structure.—Composed of layers

Substructure.—The part of any

Superstructure.—The part of a structure

Strut.—A bridge member carrying compression

Angle Strut.—A strut built up of angle

Box Strut.—Any strut built of structural

Channel Strut.—A strut built up of channels

Collision Strut.—A strut placed against a
inclined end post of a bridge so that, in case of
ing the said end post, the shock will be
and not be taken up in bending by the

Counter Strut.—A web member subject to

Horizontal Strut.—A compression member

Inclined Strut.—A compression member placed

Intermediate Strut.—An overhead strut in
opposite trusses and lying between the upper
bridges, if used at all, it would be between the

Laced Strut.—A strut that has lacing of small
face or faces.

Lateral Strut.—A strut in the lateral system of a

Overhead Strut.—A strut in the overhead portion

Pedestal Strut.—A strut connecting and bracing two

Portal Strut.—A strut in the portal bracing of a

Radial Strut.—One of a series of struts radiating
of a wheel, or the radial braces of a turntable,

Secondary Strut.—A secondary member taking up

Star Strut.—A strut formed of either two or four
two-angle form is not a satisfactory type, as it fails
strength as might properly be anticipated.

Stiffening Strut.—A strut used to overcome a buckling
mediate point of a post or column and thus reduce

Sub-strut.—A sub-diagonal carrying compression.

Sway Strut.—A strut used in sway bracing.

Timber Strut.—A strut made of timber.

Vertical Strut.—A vertical compression member.

Stub Abutment.—Same as "Straight Abutment." See

Stub Switch.—See "Switch."

Stud.—A short projecting pin. An upright member
attached.

Stud Bolt.—See "Bolt."

Studding.—Same as "Stud," *q.v.*

Stud-link Chain.—See "Chain."

Stuffing Box.—See "Box."

Stump Joint.—See "Joint."

Sub-contract.—See "Contract."

Sub-contractor.—See "Contractor."

Sub-diagonal.—A secondary member connecting the mid-point of a main diagonal with an adjacent panel point.

Sub-divided Panel.—See "Panel."

Sub-divided Pratt Truss.—See "Truss."

Sub-divided Warren Truss.—See "Truss."

Sub-foreman.—See "Foreman."

Sub-grade.—See "Grade."

Sub-letting.—See "Letting."

Submerged Pier.—See "Pier."

Sub-post.—See "Post."

Sub-punch.—See "Punch."

Sub-sill.—See "Sill."

Sub-soil.—The stratum of earth lying immediately under the surface soil.

Substructure.—The piers, pedestals, and abutments of a bridge or trestle.

Sub-strut.—See "Strut."

Sub-tie.—See "Tie."

Sub-vertical.—See "Vertical."

Suction.—A drawing up of a liquid by the production of a partial vacuum in a space connected with the said fluid.

Suction Hose.—See "Hose."

Suction Pipe.—See "Pipe."

Suction Pump.—See "Pump."

Sudden Stress.—See "Stress."

Sulphur.—An elementary substance which occurs in nature, characterized by a yellow color, a brittle, crystalline structure, a resinous lustre, and strong acrid fumes given off during combustion. Used sometimes in bridgework for filling around bolts in masonry.

Sump, or **Sump-hole.**—A depression or hole in a pier foundation, used to collect drainage water so that it may be pumped out; also a hole under a building or in a tunnel for the same purpose.

Super-elevation.—See "Elevation."

Superintendent.—The person having complete control of a piece of work.

Day Superintendent.—The person in complete control of work during the day.

Night Superintendent.—The person in complete control of work during the night.

Superstructure.—That portion of a bridge or trestle lying above the piers, pedestals, and abutments.

Supplement.—An addition to anything to make it complete. To add anything for that purpose.

Supplementary.—Being in the nature of a supplement.

Supply Shaft.—See "Shaft."

Supporting Machinery.—See "Machinery."

Surbase.—A border or moulding above a base.

Surcharge.—To overcharge. The earth that lies both above and behind a retaining wall.

Surface.—The condition of a track as to vertical evenness and smoothness.

Surface Condenser.—See "Condenser."

Survey.—To determine the boundaries, extent, position, elevation, etc., of a portion of the earth's surface by means of lineal and angular measurements. The result of such a process is also termed a survey, as is also the process itself.

Surveying.—The art of making surveys.

[illegible] Cable.—See "Cable."

[illegible] Rod.—One of the rods [illegible]
purpose of supporting the floor

Swab.—A mop used for spreading [illegible]
bearings for paving blocks.

Swage, or Swedge.—A die or former [illegible]
shape with a swaging block.

Sway.—To brace laterally or longitudinally

Sway Bolt.—See "Bolt."

Sway Bracing.—See "Bracing."

Sway Strut.—See "Strut."

Sweating.—A method of fastening two [illegible]
thin invisible layer of solder.

Swedge.—Same as "Swage," *q.v.*

Swedged Bolt.—See "Bolt."

Swedish Iron.—See "Iron."

Swelled Column.—A column that is larger at the

Swing Bridge.—See "Bridge."

Swinging Crane.—See "Crane."

Swinging Scaffold.—See "Scaffold."

Swing Span.—See "Span."

Swipe.—To strike or drive with great force.

Switch.—A device for changing or shifting a [illegible]
diverted. An apparatus for turning on and [illegible]

Automatic Switch.—A switch that is worked [illegible]
used principally by street railways; also in [illegible]

Derailing Switch.—A switch operated by [illegible]
which will derail a train of cars.

Replacing Switch.—A device used for replacing [illegible]
cars.

Split Switch, or Point Switch.—A switch having a [illegible]
against the other rail, thus giving a continuous [illegible]

Stub Switch.—A switch with the ends of the rails of [illegible]
cut off square, the switch rails being firmly [illegible]
rails that lead toward the switch moving with a [illegible]
are used only at yards.

Switch-back.—A method or system of track construction [illegible]
steep slope by zigzagging back and forth over a [illegible]
with each other by switches.

Switch Bar.—See "Bar."

Switching Locomotive.—See "Locomotive."

Switch-signal.—A signal to apprise the train crew [illegible]
In the daytime a swinging arm is used and at night [illegible]

Switch-stand.—The stand on one side of a track [illegible]
is worked.

Swivel.—A device consisting of a U-shaped bar attached to a plate having a hole in its centre through which passes the headed shank of a hook, thus permitting of an axial rotation of either part.

Swivel Bridge.—Same as "Swing Bridge." See "Bridge."

Swivel Hanger.—A hanger for shafting with pivoted boxes to permit a certain amount of play and adjustment in the motion of the shaft.

Swivel Head.—The upset end of the swivel hook, enlarged to prevent it from slipping through the eye in the U-shaped half of the swivel.

Swivel Hook.—The half of the swivel that works through the washer or small circular plate fastened to the U-portion of the device and to which the rope or chain is attached.

Swivel Joint.—See "Joint."

Swivel Wrench.—See "Wrench."

Sword.—A hand tool in the shape of a small sword, used for filling with mortar the joints in masonry.

Syenite.—A rock composed of feldspar and hornblende with very little or no quartz.

Sylvester-wash.—The alternate applications of a solution of soap and one of alum to the dry surface of concrete construction so as to render the same impervious to water.

Symmetry.—A condition of equality or balance of shape, size, and position between similar parts of a figure or body about a central axis.

Axis of Symmetry.—A line about which the parts of a figure or body are symmetrically disposed.

Centre of Symmetry.—The intersection of the axes of symmetry.

Plane of Symmetry.—A plane about which the parts of a figure or a body are symmetrically disposed.

Sypher Joint.—See "Joint."

T

Table of Data.—A list of the known circumstances that affect the designing of a structure.

T-Abutment.—See "Abutment."

Tackle.—A combination of ropes and pulley-blocks used in hoisting or lowering where a multiplication of force is desired. Same as "Block and Falls."

Boom Tackle.—The tackle used for manipulating the boom of a derrick.

Differential Tackle.—See "Differential Block."

Efficiency of Tackle.—The ratio of the actual load lifted to the theoretical load (*i. e.*, the pull on the fall line multiplied by the number of parts of the rope sustaining the load.)

Fleeting Tackle.—A horizontal subsidiary tackle used in connection with the main hoisting tackle to fleet members into place.

Gin Tackle.—A system of pulleys consisting of a double and a triple block, the standing end of the fall line being made fast to the double block, which is movable.

Luff Tackle.—The tackle used to hold the boom of a derrick from swinging sideways.

Tackle Block.—See "Block."

Tackle Hook.—See "Hook."

Tag Line.—See "Line."

Tail Block.—See "Block."

Tailings.—Refuse material from the mines. Also called chats. Used for making concrete.

Tail Wall.—See "Wall."

Take-up.—A device for taking up lost motion.

Talus.—The mass of fragmentary rock or soil which accumulates at the foot of a hill, slope, or cliff as disintegration proceeds above.

[illegible]

[illegible]

[illegible]

Tangent.—A straight line [illegible]
straight part of a railroad [illegible]

Tangential Stress.—See "Stress."

Tank Locomotive.—See "Locomotive."

Tap.—A tool for cutting threads in a hole [illegible]

Tap Bolt.—See "Bolt."

Tape.—A long, narrow ribbon of [illegible]

Bridge Tape.—A strong flat wire divided [illegible]
divided decimally.

Chain Tape.—A thin steel ribbon graduated [illegible]
side in surveyor's links.

Metallic Tape.—A tape made of cloth, [illegible]
give strength and to reduce the stretching [illegible]

Standardized Tape.—A tape that has been [illegible]
length.

Steel Tape.—A tape made of steel. Used for [illegible]

Tape Measure.—Same as "Tape," *q.v.*

Taper.—To diminish in section regularly and [illegible]

Taper File.—See "File."

Taper Shank Drill.—See "Drill."

Tap Wrench.—See "Wrench."

Tar.—A thick, dark, viscous liquid obtained by the [illegible]
such as wood, coal, peat, etc.

Target.—A sliding disk on a level rod, used for fixing [illegible]
as determined by an engineer's level.

Tarpaulin.—A heavy canvas sheet used to cover [illegible]
porarily.

Tarred Paper.—See "Paper."

Tassel.—Same as "Corbel," *q.v.*

Taut.—Tight; tense; not slack.

T, or Tee Beam.—See "Beam."

T-Beam Girder.—See "Girder."

Teat.—Same as "Tit," *q.v.*

Teat Drill.—See "Drill."

T-Iron.—Same as "Tee," *q.v.*

Telemeter Rod.—Same as "Stadia Rod," *q.v.*

Telescope.—That part of an engineer's transit or level [illegible]
nifying objects.

Telltale.—An indicator. A row of straps or ropes [illegible]
track so as to strike any one standing on a car-roof [illegible]
is about to pass under or through a bridge or similar [illegible]

Temper.—To bring a metal, such as steel, to a proper [illegible]
dition of steel relative to the degree of hardness.

Temperature.—The intensity of the sensible heat of a body.

Temperature Stress.—See "Stress."

Tempered Steel.—See "Steel."

Tempering.—The act of producing a temper in steel or [illegible]

Oil Tempering.—A process of plunging red-hot steel [illegible]
frequently used for oil hardening because the effect [illegible]
of quenching in water and then drawing the temper [illegible]
of a moderate heat.

Tempering.

Water Tempering.—A process of heating hardened steel to draw the temper (lower the degree of hardness) and quenching in water when the desired condition (as indicated by the color) is attained.

Tempering of Mortar.—See "Mortar."

Temper of Steel.—See "Steel."

Templet, or **Template.**—A full-sized pattern, generally made of wood and used to lay off work in bridge shops.

Templet Punch.—See "Punch."

Tenacity.—That property of a body by which it resists being pulled apart.

Tender.—The attendant at a bridge or on a part of construction work. A bid on a piece of construction work. An offer to do work for a consideration. A car attached to a locomotive for carrying a supply of fuel.

Inside Lock Tender.—The man inside the air-lock who manipulates the pressure valve and the opening of the lock doors.

Lock Tender.—The man who operates the air-lock in pneumatic sinking of bridge piers.

Outside Lock Tender.—The man outside of the air-lock who assists in operating it.

Tenon.—A projection, properly of rectangular cross-section, at the end of a piece of timber, to be inserted into a socket or mortise in another timber, so as to make a joint.

Tensile.—Pertaining to tension. The character of the force which tends to separate, in the most direct manner possible, the adjoining parts of a body.

Tensile Resistance.—See "Resistance."

Tensile Strain.—See "Strain."

Tensile Strength.—Same as "Tensile Resistance," *q.v.*

Tensile Stress.—See "Stress."

Tension.—The state or condition of being stretched.

Direct Tension.—Tension applied parallel to the axis of the member and uniformly over its cross-section.

Initial Tension.—Tension applied to a member before it is subjected to the principal load.

Tension Bar.—See "Bar."

Tension Beam.—See "Beam."

Tension Bolt.—See "Bolt."

Tension Brace.—See "Brace."

Tension Joint.—See "Joint."

Tension Member.—See "Member."

Tension Rod.—See "Rod."

Ten-wheeled Locomotive.—See "Locomotive."

Teredo Navalis.—A worm-shaped, marine mollusc having a shell with two small valves at its head with which it bores into submerged wood.

Terra Cotta.—A hard pottery used for building purposes.

Test.—A method for determining the properties of a material. The act of testing.

Bending Test.—A test made by bending bars to determine their comparative brittleness. A test made on beams to determine their moduli of rupture.

Boiling Test.—A test for determining the constancy of the volume of cement. Pats of cement mortar are made, protected against drying for twenty-four hours, then put in hot water or steam for five hours, after which they are removed and observed for signs of cracking and disintegration. If no such signs appear, the cement has proved satisfactory in respect to soundness.

Heat Test.—Same as "Boiling Test," *q.v.*

Specimen Test.—A test of a portion of the material to be used in the construction of a structure.

[illegible]

Thimble Joint.—See "Joint."

Thinner.—A liquid, such as turpentine, [illegible] or to reduce its viscosity. [illegible] painting.

Non-volatile Thinner.—That portion [illegible] current of steam at atmospheric [illegible]

Volatile Thinner.—All that liquid portion [illegible] stilled in a current of steam at atmospheric [illegible]

Third-class Masonry.—See "Masonry."

Thoroughfare.—Any street, alley, water[illegible] any kind.

Thread.—The helix cut on the shank of a bolt [illegible]

Left-handed Thread.—A spiraling in such [illegible] rotation of the bolt or screw produces a [illegible]

Pitch of Thread.—See "Pitch."

Pressed Thread.—A thread made by pressing [illegible]

Right-handed Thread.—A spiraling in such [illegible] the bolt or screw produces a forward motion [illegible]

Screw Thread.—The thread on a screw, having [illegible]

Square Thread.—A thread having a square or rect[illegible]

Standard Thread.—A thread having the shape of [illegible] to some standard such as the American Bridge [illegible]

V-Thread.—A thread having a cross-section like [illegible]

Thread Cutter.—See "Cutter."

Three-hinged Arch.—See "Arch."

Through Bolt.—See "Bolt."

Through Bridge.—See "Bridge."

Through Cantilever.—See "Cantilever."

Through Girder.—See "Girder."

Through Span.—See "Span."

Through Truss.—See "Truss."

Thrust.—To push. The amount of push.

Horizontal Thrust.—A thrust in a horizontal direction[illegible]

Longitudinal Thrust.—A thrust along the longitudinal [illegible]

Thrust Angle.—See "Angle."

Thrust Axle.—See "Axle."

Thrust Bearing.—See "Bearing."

Thrust Collar.—See "Collar."

Thrust of an Arch.—See "Arch."

Thumb Nut.—See "Nut."

Thumb Screw.—See "Screw."

Tide Gauge.—See "Gauge."

—A piece of timber used in railroads for supporting and holding the [illegible] sleeper. A tension member of a truss.

veled Tie.—A railroad tie in which the top and the bottom faces are [illegible] at one end than at the other.

ss Tie.—A railroad tie or sleeper.

agonal Tie.—A tension diagonal incapable of resisting compression.

ty Tie.—A timber tie affected by a certain fungous disease.

lf Round Tie.—A slabbed tie having greater width on the lower than on the [illegible] face.

art Tie.—A railroad tie showing sapwood on one or two corners only and which sapwood does not measure more than one inch on either corner [illegible] diagonally across the end of the tie.

wed Tie.—A railroad tie which is hewed on at least two sides.

ky Tie.—A tie made from a cypress tree that is affected with a fungous disease, known locally as peck.

e Tie.—A tie made from a tree of such size that not more than one tie can be made from a section—hewed or sawed on two parallel faces.

artered Tie.—A tie made from a tree of such size that four ties only can be made from a section.

p Tie.—A tie which shows more than the prescribed amount of sapwood in cross-section.

b Tie.—A tie made from a slab.

abbed Tie.—A tie sawed on the top and bottom only.

t Tie.—A tie made from a tree of such size that, by splitting, two or more ties can be made from a section.

ht Heart Tie.—A tie having no sapwood.

b-tie.—A tension member in a subdivided panel of a truss.

eated Tie.—A tie which has been subjected to a preservative process, such as saturation with creosote under heat and pressure.

ane Tie.—A square tie showing part of the original surface of the tree on one or more corners.

ar.—See "Bar."

eam.—See "Beam."

olt.—See "Bolt."

ammer.—See "Hammer."

ine.—See "Line."

Plate.—Same as "Batten Plate." See "Plate."

—A row or series. Restricted to vertical direction. A vertical division or panelling in a trestle tower.

Rod.—See "Rod."

Spacing.—The interval between ties. Also the distance from centre to centre of ties.

—An earthenware pipe used for drainage.

anza Tile.—A reinforced composition cement tile used in roofing.

wn Tile.—A roofing tile used at the hips or ridges of roofs.

Floor.—See "Floor."

—To forge with a tilt hammer.

ammer.—See "Hammer."

er Bent.—Same as "Frame Bent," *q.v.*

er Bolt.—See "Bolt."

er Buggy.—See "Buggy."

er Casing.—See "Casing."

er Coupling.—See "Coupling."

er Dogs.—See "Dog."

er Floor.—See "Floor."

[illegible]

Timber Hook.—Same as "Timber

Timber Lath.—See "Lath."

Timber Lathe.—See "Lathe."

Timber Pins.—See "Pins."

Timber Truck.—A frame mounted on four
porting timber short distances.

Timber Strut.—See "Strut."

Tint.—A color produced by the admixture
white pigment or paint, the white

Tinting Strength.—The power of coloring
as a medium standard for estimating

Tipper.—A type of draw span supported at
by a beam which, in turn, rests upon
as to produce an equal reaction at each

T-Iron.—See "Iron."

Tit.—A small accidental projection on a casting

Tit Drill.—See "Drill."

Toe.—The foot of a slope. The front part of the

Toe-nail.—To fasten a board or timber to the
through the end or edge of the first timber

Toggle.—A mechanical device consisting of two
common ends and pivoted at the other
ally to its line of application.

Toggle Bolt.—See "Bolt."

Toggle Iron.—See "Iron."

Toggle Joint.—See "Joint."

Toggle Riveter.—See "Riveter."

Ton.—A unit of weight, generally equal to two

Foot Ton.—A unit of work equal to that involved in
through the space of one foot, or in raising one

Inch Ton.—A unit of work equal to that involved

Long Ton.—A unit of weight equal to 2,240 pounds
and steel rails. It is the English ton.

Metric Ton.—A French ton, equivalent to 2,205

Short Ton.—A ton of two thousand pounds.

Tone.—The color which principally modifies a hue or a

Ton-foot.—Same as "Foot-ton," *q.v.*

Tongs.—A tool for grasping objects, consisting of two
a common centre.

Hammer Tongs.—A pair of tongs which is designed
tools or hammer heads which are red hot.

Pipe Tongs.—A hand tool for grasping and turning
bent bars forming a jaw near one end, where it
other end fashioned into handles.

Rail Tongs.—Tongs with hooked ends and spreading

Rivet Tongs.—Tongs used by riveters for throwing

Tongue and Groove.—A term applied to lumber in
recess for receiving the projecting tongue of the
site edge has a projecting tongue to fit into the

Tongued and Grooved Joint.—See "Joint."

Tongue Joint.—See "Joint."

Tongue Plate.—See "Plate."

Tool.—Any thing, device, or apparatus used to facilitate mechanical operations; usually restricted to small implements.

Balling Tool.—A hand tool used for collecting into a mass the iron in a puddling furnace.

Calking Tool.—A tool used for the process of calking.

Cutting Tool.—A tool used for cutting materials.

Heading Tool.—A tool for the swaging of bolt heads.

Radius Tool.—A tool used by cement finishers to form a round corner on exposed concrete work.

Tool Box.—See "Box."

Tool Chest.—A chest or covered box for the storing or shipping of tools.

Tool Dressing.—See "Dressing."

Tooled Ashlar.—See "Ashlar."

Tool Finish.—Same as "Tool Dressing," *q.v.*

Tool House.—A house for the storage and safe-keeping of tools.

Tooling.—The act of operating with a tool upon an object.

Tool Steel.—See "Steel."

Tooth.—The projection or cog on a gear wheel which meshes with a like projection on another similar gear.

Epicycloidal Tooth.—A form of gear tooth having both faces and flanks curved to conform with arcs of an epicycloid.

Face of Gear Tooth.—The part of the rolling surface of a gear tooth outside the pitch circle.

Flank of Gear Tooth.—The part of the rolling surface of a gear tooth inside the pitch circle.

Involute Tooth.—A form of gear tooth in which the faces conform to an arc of an involute and the flanks to radial planes.

Point of Gear Tooth.—The outer end of a tooth on a gear wheel.

Rack Tooth.—The tooth on a rack which meshes with a gear.

Root of Tooth.—The base of the tooth where it joins the rim of the wheel.

Tooth Axe.—See "Axe."

Tooth Axed Dressing.—A form of stone dressing. See "Dressing."

Toothed Chisel.—See "Chisel."

Toothed Dressing.—See "Dressing."

Toothed Wheel.—See" Wheel."

Toothing.—A general term for a system of teeth.

Tooth Pitch.—Same as "Circular Pitch."

Tooth Pressure.—See "Pressure."

Top Chord.—See "Chord."

Top Lateral Bracing.—See "Bracing."

Topographical Map.—See "Map."

Torque.—The moment of a force or a system of forces tending to produce rotation. The starting capacity of a rotative machine.

Torsion.—The twist or deformation of a body set up by a torque.

Angle of Torsion.—The amount of twist or deformation produced by a torque.

Coefficient of Torsion.—The angle of torsion produced in a wire of unit dimension by a force acting with unit moment.

Moment of Torsion.—The sum of all the moments of the internal forces in a body that is resisting a twisting moment. It is equal to the sum of the moments of all the applied forces that tend to produce torsion

Torsional Strain.—See "Strain."

Torsional Stress.—See "Stress."

[illegible]

[illegible]—See "Bracing."

[illegible]—See "Panel."

[illegible]—See "Span."

[illegible] Truss.—See "Truss."

Tracing.—A drawing made on [illegible]
a drawing placed beneath.

Tracing Cloth, or Tracing Linen.—[illegible]
or sizing making it transparent [illegible]

Tracing Paper.—See "Paper."

Track.—A set of rails or plates and their [illegible]
structure provided with wheels or rollers.

Double Track.—A track consisting of [illegible]

Lorry Track.—A track on which a lorry [illegible]
around blast furnaces and coal tipples [illegible]

Side Track.—A secondary track parallel to [illegible]
railroad.

Single Track.—A track with a single pair of [illegible]

Spur Track.—A short track leading from the [illegible]
end only.

Track Bolt.—See "Bolt."

Track Gauge.—See "Gauge."

Track Jack.—See "Jack."

Track Joists.—See "Joist."

Track Maul.—See "Maul."

Track Pile-driver.—See "Pile-driver."

Track Rail.—See "Rail."

Track Segment.—See "Segment."

Track Spacing.—The arrangement of tracks with [illegible]
between track centres of adjacent tracks.

Track Spike.—See "Spike."

Track Stringer.—See "Stringer."

Track Tie.—Same as "Cross Tie," See "Tie."

Track Walker.—A man who makes regular inspection [illegible]

Track Wrench.—See "Wrench."

Traction.—The force required to draw a body. The [illegible]
wheel on a rail.

Traction Bracing.—Same as "Train Thrust Bracing."

Traction Load.—See "Load."

Traction Stress.—See "Stress."

Traction Thrust.—Same as "Traction Load," q.v.

T-Rail.—See "Rail."

Train Thrust Bracing.—See "Bracing."

Tram.—A small car used on a tramway.

Tram Crane.—Same as "Traveling Crane."

[illegible].—A drawing instrument for describing circles of large radii. [illegible] bar and two sliding parts which can be adjusted to the desired position by moving them along the bar. One sliding part is provided with a point for centering, the other with a pen or pencil for drawing the curve. Called also a "Beam Compass."

[illegible]way.—A temporary track built near a bridge and used in connection with trestles for transporting materials to the work.

[illegible]cendental Curve.—See "Curve."

[illegible]ferred Load.—See "Load."

[illegible]ferred Load Stress.—See "Stress."

[illegible]formed Catenary.—See "Catenary."

[illegible]it.—An engineer's instrument for running lines, measuring or laying off angles, obtaining differences in elevations, etc., in field work. It consists of a telescope mounted on a horizontal axle and capable of a complete revolution. The standards supporting the axle are attached to a horizontal plate capable of rotation in its own plane. These two rotations permit of the measurement of vertical and horizontal angles and the projection of a line in any direction.

[illegible]ition Curve.—Same as "Easement Curve." See "Curve."

[illegible]itman.—The man who operates the transit.

[illegible]t Point.—A point over which the transit is set.

[illegible]verse.—Extending across. Crosswise direction.

[illegible]verse Beam.—See "Beam."

[illegible]verse Bracing.—See "Bracing."

[illegible]verse Component.—See "Component."

[illegible]verse Girder.—See "Girder."

[illegible]verse Line.—See "Line."

[illegible]verse Load.—See "Load."

[illegible]verse Section.—See "Section."

[illegible]verse Shear.—See "Shear."

[illegible]sverse Strain.—See "Strain."

[illegible]sverse Stress.—See "Stress."

[illegible]sverse Vertical Bracing.—Same as "Transverse Bracing," *q.v.*

[illegible]p.—A hard, dark-colored, volcanic rock used for concrete roadway pavements, and ballast for railroads. Also a device that will intercept material in flowing water.

[illegible]d Trap.—A device for separating sand from water.

[illegible]ss.—A gray, yellow, or whitish earth made up in large part of comminuted pumice or other volcanic material. Resembles pozzuolana. Used for making hydraulic cement.

[illegible]veler.—A form of derrick mounted on wheels, used in the erection of bridges.

[illegible]eeper Traveler.—A small movable derrick running on a track on the upper chord of a truss. It usually has two booms. A mule traveler.

[illegible]ntry Traveler.—A framework of two or three bents or gallows frames, braced longitudinally and carried on a track supported on falsework and placed outside of the trusses. The traveler clears the span at all points and can be rolled back and forth as needed. It carries a number of blocks and tackles which are operated by a hoisting engine placed on a platform near the base. It is used in erection for hoisting and placing the members of a truss.

[illegible]eler Wheel.—See "Wheel."

[illegible]eling Crane.—See "Crane."

[illegible]eling Girder.—See "Girder."

[illegible]erse Line.—See "Line."

[illegible]d.—The bearing surface of a wheel or of a rail. The steps of a stairway.

[illegible]d Tie.—See "Tie."

[illegible]d Timber.—Timber which has been subjected to a preservative process.

[illegible]

[illegible]—A long, narrow [illegible]

Trestle.—A bridge structure [illegible]
girders forming the floor system.

Braced Trestle.—A trestle having braced

Knee-braced Trestle.—A trestle provided

Pile Trestle.—A trestle having pile bents

Trestle Bent.—See "Bent."

Trestle Bridge.—See "Bridge."

Trestle Cap.—See "Cap."

Trestle Work.—See "Work."

Triangle.—A figure bounded by three

Force Triangle.—A system of three forces
of a triangle drawn parallel and with

Triangular File.—See "File."

Triangular Girder.—See "Girder."

Triangular Lattice Truss.—See "Truss."

Triangular Scale.—See "Scale."

Triangular Truss.—See "Truss."

Triangulation.—The process of locating points
of triangles constructed on a measured
adjacent angles.

Triangulation Hub.—See "Hub."

Triangulation Point.—The point at the corner of the
is set in order to measure the angle.

Triangulation Sheet.—The drawing upon which is
a bridge with the dimensions thereof.

Tricalcic-silicate.—The chief constituent of Portland
ment composed of calcium, oxygen, and silicon,
$3CaO.SiO_2$.

Trigonometric Function.—See "Function."

Trip.—A device for tripping or releasing a hammer,

Trip Hammer.—See "Hammer."

Triple Block.—See "Block."

Triple Cancellation.—See "Cancellation."

Triple Intersection.—Same as "Triple Cancellation."

Trip Line.—See "Line."

Tripod.—An arrangement of three legs pivoted to a head
instrument such as a transit or a level.

Trolley.—A small flanged wheel arranged to run upon a

Trough Floor.—See "Floor."

Trough Plate.—See "Plate."

Trough Plate Floor.—See "Floor."

Trowel.—A mason's tool consisting of a handle and a
handling mortar.

Hand Float Trowel.—A form of trowel having squared
them.

Troweled Finish.—See "Finish."

Troy Rod.—See "Rod."

Truck.—A small vehicle consisting of a frame mounted on
of four or more wheels in a frame supporting one end

Truck.—A railway truck mounted on two or more pairs of wheels and attached to a car or locomotive engine by means of a vertical king pin about which it turns so as to facilitate the rounding of curves in the track.

mber Truck.—A frame mounted on four wheels which run on rails. Used for transporting timber. Any small wheeled apparatus for moving timber.

Jack.—See "Jack."

Discount.—See "Discount."

Horsepower.—Same as "Indicated Horsepower." See "Horsepower."

Stress.—See "Stress."

ncated Bow String Truss.—See "Truss."

ndle.—Same as "Lantern Wheel," *q.v.*

nnion.—A form of short axle attached to the side of a body.

nnion Bascule Bridge.—See "Bascule."

ss.—A framed or jointed structure designed to act as a beam while each of its members is primarily subjected to longitudinal stress only.

Truss.—A four-panel truss having extended batter posts intersecting over the centre resembling somewhat the letter A. See Fig. 22*dd*.

rch Truss.—A truss having an arched upper chord in compression and a straight bottom chord or tie rod with vertical hangers.

altimore Truss.—A truss composed of parallel chords and subdivided panels. See Figs. 22*c* and 22*d*.

ollman Truss.—A trussed beam, each panel-load being carried directly to the ends of the upper chord by two inclined tension members, there being no stress in the lower chord. Properly speaking, it is not a truss, but a multiple suspension system. See Fig. 22*o*.

owstring Truss.—A truss in which the lower chord is horizontal and the upper chord joints lie in the arc of a parabola, or similar curve. See Fig. 22*s*.

ridge Truss.—Any truss used in a bridge span.

urr Truss.—A timber truss with counter-struts inserted throughout the entire length giving very great rigidity.

Camel-back Truss.—A truss having a broken outline for the upper chord taking the humped shape of a camel's back. See Figs. 22*ee* and 22*ff*.

Cantilever Arch Truss.—A cantilever truss having the shape of a portion of an arch.

Cantilever Truss.—A truss overhanging its support at one end and anchored down at the other.

Continuous Truss.—A truss which extends over three or more supports.

Crescent Truss.—A truss with both chords curved upward, or both downward, and making sharp intersections with each other at the ends, producing in outline the appearance of a crescent, the web system being of the triangular type.

eck Truss.—A loose expression for the truss of a deck span.

Double Bowstring Truss.—A truss in which the joints of each chord lie in curves concave to each other. See Fig. 22*r*.

Double Intersection Truss.—A truss having two intersecting diagonals for each panel. See Fig. 22*i*.

Double Triangular Truss.—Same as "Double Intersection Truss," *q.v.*

nk Truss.—Properly, a trussed beam. See Fig. 22*n*.

alf-through Truss.—A loose expression for the truss of a half-through span.

og-chain Truss.—Properly a trussed beam. Same as an inverted "Queen Post Truss," *q.v.*

orizontal Truss.—A truss placed in a horizontal plane.

owe Truss.—A form of truss in which the vertical members of the web take tension and the diagonal members compression. See Fig. 22*p*.

ermediate Truss.—The centre truss of a three-truss span.

[illegible] Truss.—A truss having [illegible]

[illegible] Truss.—A Whipple Truss [illegible]

[illegible] Truss.—Same as "[illegible]

Parabolic Truss.—A bow-string truss [illegible] parabola. See Fig. 22s.

Parker Truss.—A more economical [illegible] is polygonal. See Fig. 22b.

Pegram Truss.—A form of truss having [illegible] in the arc of a circle and inclined web [illegible]

Pennsylvania Truss.—A Petit truss with [illegible] 22f.

Petit Truss.—A modified form of the Pratt [illegible] 22c, 22d, 22e, and 22f.

Pin-connected Truss.—Any truss having its [illegible]

Pony Truss.—A low truss without any overhead [illegible]

Post Truss.—See Fig. 22q.

Pratt Truss.—A type of truss having parallel [illegible] members of tension diagonals and compression [illegible]

Primary Truss.—A main truss which supports [illegible]

Quadrangular Truss.—Same as "Pratt Truss," [illegible]

Queen Post Truss.—A type of trussed beam having [illegible]

Riveted Truss.—Any truss having its main members [illegible]

Roof Truss.—Any truss used in supporting a roof. [illegible]

Schwedler Truss.—A modification of the Whipple [illegible]

Secondary Truss.—A truss supported by another truss [illegible]

Single Intersection Truss.—A truss with one web system [illegible]

Stiffening Truss.—A truss used in connection with a [illegible] the load over the length thereof.

Subdivided Warren Truss.—A Warren truss with verticals [illegible] subverticals. It bears the same relation to Fig. [illegible] Pratt truss.

Through Truss.—A loose expression for a truss of a through [illegible]

Town Truss.—A form of lattice truss having double [illegible] systems in different planes. See Fig. 1f.

Triangular Lattice Truss.—See Fig. 22t.

Triangular Truss.—A truss having inclined web members [illegible]

Truncated Bow-string Truss.—A bow-string truss with [illegible]

Warren Truss.—A form of triangular truss composed [illegible] Fig. 22k.

Whipple Truss.—A double intersection Pratt truss. See [illegible]

Wind Truss.—A truss to carry a wind load.

Windward Truss.—The truss next to the wind.

Truss Block.—See "Block."

Truss Bridge.—See "Bridge."

Truss Deformation.—See "Deformation."

Truss Depth.—See "Depth."

Trussed Arch.—Same as "Braced Arch," *q.v.*

Trussed Beam.—See "Beam."

Trussed Eye-bars.—See "Eye-bar."

Trussed Girder.—See "Girder."

Truss Element.—See "Element."

Truss Girder.—See "Girder."

Trussing.—A system of rods attached to the ends of a beam, girder, or column and held therefrom by short struts between the member and the rods.

Truss Joint.—See "Joint."

Truss Member.—Same as "Truss Element," *q.v.*

Truss Pin.—See "Pin."

Truss Rod.—See "Rod."

Truss Shop.—A shop where bridge trusses are manufactured.

Truss Spacing.—The perpendicular distance between the central planes of trusses of a bridge.

Truss Span.—See "Span."

T-Square.—See "Square."

Tube.—A pipe of small size. A hollow cylinder.

Guide Tube.—A contrivance by which a boring bit or drill is guided, commonly a fixed tube to prevent swinging.

Tube-mill.—A shop where tubes are drawn.

Tubular Arch Bridge.—See "Bridge."

Tubular Bridge.—See "Bridge."

Tubular Girder.—See "Girder."

Tuck Joint.—See "Joint."

Tug.—A small, powerful boat for towing.

Tumbler.—Same as "Rattler," *q.v.*

Tungsten Steel.—See "Steel."

Tunnel.—An excavated passageway under the ground or the water.

Tup.—A ram.

Turnbuckle.—A device for tightening or drawing together two parts of a rod, consisting of a sleeve having an interior right-hand thread at one end and an interior left-hand thread at the other. This sleeve engages the threaded ends of the two pieces of rod so that a turning thereof in one direction screws up on the rods and in the reverse direction unscrews on them.

Turned Bolt.—See "Bolt."

Turned Shafting.—See "Shafting."

Turning Bridge.—Same as "Swing Bridge." See "Bridge."

Turning Point.—A point of reference on some firm object, used in levelling for resetting the instrument.

Turnout.—A railroad switch or siding.

Turnstile.—A revolving gate.

Turntable.—The framework under the swing span which transmits the load to the bearings.

Centre-bearing Turntable.—A turntable having a centre pivot for supporting the load during operation.

Double Rim-bearing Turntable.—A turntable comprising two concentric circular girders or rims, each transferring its part of the load to an independent set of rollers.

Rim-bearing Turntable.—A turntable having a circular girder, or rim, to transfer the load to a set of rollers.

Turntable Girder.—See "Girder."

[illegible]

[illegible] tube or pipe [illegible]

Twist.—A rotation of one body [illegible] part of the same body.

Angle of Twist.—Same as the "Angle [illegible]

Twist Drill.—See "Drill."

Twist Drill Grinder.—An emery wheel [illegible] justable rest for holding the [illegible]

Twisting Moment.—Same as "Torque," [illegible]

Twist Joint.—See "Joint."

Two-blocks.—An expression used by [illegible] ping point or limit has been reached, [illegible] tackle being overhauled until the two blocks [illegible] tion in the same direction is possible. [illegible]

Two-hinged Arch.—See "Arch."

U

U-Abutment.—See "Abutment."

U-Bolt.—See "Bolt."

Ultimate Resistance.—See "Resistance."

Ultimate Strength.—Same as "Ultimate Resistance [illegible]

Ultimate Stress.—See "Stress."

Unbalanced Bid.—See "Bid."

Unbalanced Load.—See "Load."

Unbalanced Wheel.—See "Wheel."

Uncoursed Rubble.—Same as "Random Rubble." [illegible]

Underdrain.—To drain by forming channels underground [illegible]

Undermine.—To excavate beneath a structure.

Underpin.—To pin or support an existing wall by [illegible] it and building in piers, after which further [illegible] and the spaces then are filled with solid walls.

Underpinning.—The process of placing underpins. [illegible] of underpins.

Unequal Coursing.—Same as "Random Coursing." [illegible]

Unfilleted.—Without fillets. Sharp cornered.

Uniform Load.—See "Load."

Uniform Load Stress.—See "Stress."

Uniform Resistance.—See "Resistance."

Uniform Section.—See "Section."

Uniform Strength.—Same as "Uniform Resistance," [illegible]

Uniform Stress.—See "Stress."

Union.—A form of coupling, used for connecting two pieces [illegible]

Flange Union.—A type of pipe connection consisting of [illegible] bored and tapped to screw on the ends of the pipes, [illegible]

Pipe Union.—A form of pipe connection, employed for [illegible] of pipes. Its essential features are two end pieces [illegible] and fit into each other, also an outer ring or sleeve [illegible] one side, which bears against one of the end pieces at [illegible] on the other end piece, thus pulling the two ends together [illegible]

Union Joint.—See "Joint."

Unit Cost.—See "Cost."

Unit Price.—The price per unit of magnitude, such as the [illegible] square foot, per cubic yard, etc.

Stress.—See "Stress."

Weight.—The weight per unit of magnitude, as the weight per cubic foot.

rsal Grinder.—A grinding machine having an emery wheel mounted on a shaft with a universal joint admitting of a swinging motion in any direction.

rsal Joint.—See "Joint."

ersal Mill.—See "Mill."

ersal Mill Plate.—See "Plate."

eve.—To withdraw a rope from a set of blocks.

able.—Not fixed; not in permanent equilibrium.

pported Length.—See "Length."

pported Width.—The width of a plate between the nearest points of lateral restraint.

—See "Nut."

—Same as "Upset," *q.v.*

—The tendency of a structure, due to special loading conditions, to rise from its supports. Negative reaction.

t Stress.—See "Stress."

er Chord.—Same as "Top Chord." See "Chord."

er Deck.—See "Deck."

r Laterals.—Same as "Top Laterals." See "Laterals."

r Falsework.—See "Falsework."

r Lateral Bracing.—See "Bracing."

r Lateral Rod.—Any rod in the upper lateral system. See "Lateral Rod."

r Laterals.—See "Lateral."

r Lateral Strut.—Any strut in the upper lateral system.

r Track.—In rim-bearing draw spans, the plate attached to the bottom of the rim and bearing on the rollers.

er Track Segment.—One of the pieces composing the upper track.

t.—To thicken a piece of metal by heating and hammering on the end.

t-end.—The end of a bar or rod which has undergone the process of upsetting.

t Rod.—See "Rod."

rd Reaction.—See "Reaction."

—A rough block to be made into small forgings.

V

um Process.—An abandoned process for sinking piers. Its essential feature was the intermittent loading of the caisson by suddenly withdrawing the air from the working chamber, leaving the outside atmospheric pressure unbalanced, and thereby giving a downward impulse to the caisson. See "Trautwine" for details.

y.—A re-entrant angle formed by the intersection of two parts of a roof.

e.—A device for closing the passageway in a pipe, duct, or conduit.

r Valve.—A valve controlling the passage of air. Also a valve admitting air to a steam boiler, preventing the formation of a partial vacuum when the steam condenses.

l Check Valve.—A check valve formed by a ball resting upon a concave circular seat.

Valve.—A valve controlled by a float ball. A valve formed by a ball resting upon a concave circular seat, a form of check valve.

re Valve.—A four-way valve.

eck Valve.—A valve arranged to permit a flow in one direction only, thereby preventing the return of the fluid.

Valve.—A valve hinged at one end so as to permit the flow of the liquid in one direction only.

[illegible]

Gate Valve.—A valve having [illegible] disk parallel to the flow, [illegible] gates.

Head Valve.—The upper air-pump valve [illegible]

Hydraulic Valve.—Any valve controlling [illegible]

Leaf Valve.—Same as "Clack Valve," q.v.

Lever Valve.—A valve having a lever and [illegible] the pressure on its disk exceeds a [illegible] and permits some of the fluid to escape. [illegible] steam boilers.

Piston Valve.—A reciprocating valve, having [illegible] passage, which opens and closes successively [illegible] engine.

Receiving Valve.—A valve admitting the [illegible]

Slide Valve.—A valve having a reciprocating [illegible] cessively the admission and the exhaust [illegible]

Stop Valve.—Same as "Gate Valve," q.v.

Vanadium Steel.—See "Steel."

Van Dyke Print.—A positive print taken from a [illegible]

Vanishing Point.—A point in perspective drawing [illegible] the ground line or horizon.

Varnish.—A solution of certain gums or resins in alcohol [illegible] to produce a hard, transparent coat or surface.

Vehicle.—An oil or other medium used by painters for [illegible] Any apparatus for carrying loads.

Non-volatile Vehicle.—The liquid portion of a paint [illegible] thinner and water.

Velocity.—The rate of motion.

Angular Velocity.—The rate of angular motion.

Lineal Velocity.—The rate of lineal motion.

Virtual Velocity.—See "Virtual."

Vent or Vent-hole.—An outlet or passage for fluids.

Vermiculated.—Tortuous or sinuous like a worm.

Vermiculated Dressing.—See "Dressing."

Vernier.—A small movable scale running parallel to a [illegible] that $n + 1$ or $n - 1$ parts on the vernier are equal [illegible] scale.

Vernier Calipers.—See "Calipers."

Vernier Plate.—See "Plate."

Vertex.—The highest point, crown, or apex.

Vertical.—Upright, plumb, perpendicular to the horizon. [illegible] a truss.

[illegible]—The upright tension member attached to the pin or [illegible] of a truss and carrying a floor beam at its lower end.

Vertical.—The upright member in a subdivided panel running from [illegible] nt to the chord.

Bracing.—See "Bracing."

Clearance.—See "Clearance."

Curve.—See "Curve."

Lift Bridge.—See "Bridge."

Line.—See "Line."

Strut.—See "Strut."

—An extended bridge of many spans, mainly over dry ground. Usually [illegible] s of alternate towers and open spaces or bays.

n.—A movement back and forth. A form or mode of motion in which the oving particle occupies successive positions in recurrence.

plitude of Vibration.—The maximum movement or displacement of any particle at vibrates.

mulative Vibration.—A piling up or a superposing of vibration. An increasing bration.

iod of Vibration.—The time required for the vibrating particle to make one comete movement back and forth.

Rod.—See "Rod."

y Stress.—See "Stress."

Needle.—A small definitely weighted needle having a point of a definite, prescribed rea; used in testing the activity of cement.

Hemp.—See "Hemp."

Moment.—A term applied to the product of a force by its virtual velocity.

Velocity.—An arbitrary, infinitesimal displacement of the point of application of a force resolved into the line of action of the said force. The term is a misnomer, for it has nothing whatsoever to do with velocity.

—An appliance or tool for gripping and holding an object, consisting of two jaws and a screw with a handle for forcing the jaws together.

Vise.—A vise with an anvil on the fixed jaw.

ch Vise.—A vise constructed so that it may be attached to a bench.

d Vise.—A small vise to be held in the hand while gripping the object.

e Vise.—A vise with jaws notched to receive a pipe.

ction, or Vitrification.—The act of vitrifying.

ed Brick.—See "Brick."

y.—To convert into glass by the application of heat.

s.—The spaces between the particles of a substance or of a mixture; used in connection with sand, broken stone, or gravel for concrete.

ercentage of Voids.—The ratio of the unfilled space to the total space in an aggregate, expressed as a percentage.

e Thinner.—See "Thinner."

eter.—An electrical instrument for measuring a drop in voltage or the difference in potential between two points in a circuit.

e.—The space occupied by an object.

enometer.—An apparatus for measuring the volume of a solid body by determining the quantity of fluid which it displaces.

etric Modulus of Elasticity.—See "Elasticity."

x.—A whirlpool or eddy in a fluid.

oir.—A stone or block in the shape of a truncated wedge which forms part of an arch ring.

ead.—See "Thread."

[illegible]

[illegible]

[illegible] used by [illegible]

[illegible]

Wagon Bridge.—See "Bridge."

Wagon-way.—That portion of a floor

Wakefield Piling.—Same as "Sheet Piling,"

Wale, or Wale-piece, or Waling Strip.—A
bracing upright timbers and for

Walking Crane.—Same as "Locomotive

Wall.—A structure or slab of small

Abutment Wall.—A wall in an abutment,

Breast Wall.—Same as "Retaining Wall,"

Curtain Wall.—A thin wall. A partition

Division Wall.—Same as "Curtain Wall," *q.v.*

External Wall.—The outside wall of a structure

Face Wall.—An exposed wall, a front wall.

Foot Wall.—A low wall at the foot of an

Head Wall.—The wall at the head or main part

Masonry Wall.—Any wall made of masonry.

Parapet Wall.—Same as "Parapet," *q.v.*

Puddle Wall.—A wall of plastic clay tamped in
prevent seepage of water.

Retaining Wall.—A wall built to sustain a lateral

Slope Wall.—A thin wall of concrete or of flat
bank of earth to protect it from the erosive

Spandrel Wall.—A form of retaining wall built on an
filling.

Tail Wall.—The wall in a T-abutment set at right
the same.

Wing Wall.—One of the side walls of an abutment
wall in order to hold back the slope of an embankment,

Wall Knot.—See "Knot."

Wall Knot Crown.—See "Knot."

Wallower.—Same as "Trundle," *q.v.*

Wall Plate.—See "Plate."

Wane.—A beveled edge of a board or plank as sawn from

Wane Tie.—See "Tie."

Warp.—A twist. To twist.

Warren Girder.—See "Girder."

Warren Truss.—See "Truss."

Wash Borings.—See "Borings."

Washer.—A flat disc or plate, having a central hole,
nut at the end of a bolt, in order to distribute the
soft material.

Beveled Washer.—A washer having one side beveled
between the bolt and the timber through which the bolt

Check Washer.—A washer devised to prevent a nut from

Cup Washer.—A washer having a cup for receiving the

Friction Washer.—A thin ring of metal or other
adjoining pieces, one or both of which rotate, in
between them.

Washer.

Lip Washer.—A washer having a lip or projection that can be bent over after the nut is screwed on, thereby preventing the nut from working loose.

Lock-nut Washer.—A ring-shaped washer cut on one side and having the ends sprung laterally. Used for preventing a nut from turning.

O. G., or Ogee Washer.—A disc-shaped washer having its edge generated by an ogee curve, which was a standard curve used in Greek architecture.

Packing Washer.—A washer used between timbers to provide an open space between them when they are drawn together and bolted. The object in using them is to permit of a circulation of air between the sticks.

Plate Washer.—Any plate used as a washer.

Slot Washer.—A check washer having a slot cut at one side of the hole so that when the nut is tightened a nail can be driven through the slot, thus preventing the nut from turning.

Thickening Washer.—An additional washer used on a bolt to take up space.

Wash Mill.—An apparatus for washing sand, gravel, rock, etc.

Washout.—The destruction or displacement of a bridge, trestle, or embankment due to floods.

Waste.—Cotton used for wiping grease from machinery. Excess material from an excavation. To fail to utilize, in an embankment, material taken from a cut.

Water.—A colorless liquid chemically defined as H_2O. The run-off from a drainage basin as carried by the rivers and streams.

Extreme High Water.—The highest known water elevation of a stream or tide.

High Water.—The condition of a stream when discharging a large amount of water.

Low Water.—The condition of a stream when discharging a small amount of water.

Standard High Water.—An arbitrary high-water elevation either assumed or fixed by the War Department or some other authority.

Standard Low Water.—An arbitrary low-water elevation either assumed or fixed by the War Department or some other authority.

Water Cement.—Same as "Hydraulic Cement." See "Cement."

Water Column.—The water which rises in a vertical tube when the lower end is immersed in a current.

Water Crack.—A crack in steel due to the process of quenching it while red hot.

Water Crane.—See "Crane."

Water Cylinder.—See "Cylinder."

Water Gauge.—See "Gauge."

Water-hammer.—The shock resulting from the sudden stopping of the flow of water in a pipe.

Water Hemp.—See "Hemp."

Water Hose.—See "Hose."

Water Jet.—See "Jet."

Water Joint.—See "Joint."

Water Level.—See "Level."

Water Line.—See "Line."

Water-mark.—A mark or stain left on a bank, tree, or other object by a stream receding from high water.

Extreme High-water-mark.—A mark left by the highest known flood.

High-water-mark.—A mark left by any high water.

Low-water-mark.—A mark left by any low water.

Water Meter.—See "Meter."

Water Power.—See "Power."

Water Pressure.—See "Pressure."

Water-proof Paint.—See "Paint."

[illegible]

[illegible] forming the style.

Ways, or Launching Ways.—Supports [illegible] slides at the time of launching [illegible] unloaded on a hill-side.

Weak Iron.—See "Iron."

Wearing Floor.—See "Floor."

Weathering.—The process of seasoning [illegible]

Weather Joint.—See "Joint."

Web.—The portion of a truss or girder between [illegible] being principally to resist shear.

Open Web.—A web composed of a group of [illegible]

Solid Web.—A web composed of one or more [illegible]

Webbing.—The members or parts making up the [illegible]

Web Members.—See "Members."

Web Plate.—See "Plate."

Compound Web Plate.—A web composed of [illegible]

Web Splice.—See "Splice."

Web Stiffener.—See "Stiffener."

Web Stress.—See "Stress."

Wedge.—A solid having two inclined faces.

Guide Wedge.—A wedge-shaped apparatus used as a [illegible]

Launching Wedges.—Wedges used in supporting a [illegible]

Striking Wedge.—One of the wedges inserted [illegible] falsework and knocked out after the work is comp[illegible]

Wedge-bearing Draw.—See "Draw."

Weep-hole.—A hole in a wall for draining the water [illegible] back.

Weeping-pipe.—A pipe inserted in a wall or in any [illegible] drawing off water that otherwise would accumulate.

Weir.—A dam which discharges water over its top or crest.

Weld.—To unit two pieces of metal by heating the ends [illegible] then hammering them together. The part of the piece [illegible]

Butt Weld, or Jump Weld.—A weld in which the pieces [illegible] other and then joined by welding.

Lap Weld, or Scarf Weld.—A weld in which the ends of [illegible] over each other and then joined by welding.

Welded Head.—See "Head."

Welded Joint.—See "Joint."

Welding.—The act or process of making a weld.

Welding Hammer.—See "Hammer."

Weld Iron.—See "Iron."

Weld Steel.—See "Steel."

Well.—A vertical opening or shaft in a crib or caisson for removing materials or for the passage of workmen.

Welt.—Same as "Butt Joint," *q.v.*

Wet Blowout. Same as "Wet Suction," *q.v.*

Wet Dock.—See "Dock."

Wet Puddling.—See "Puddling."

Wet Rot.—See "Rot."

Wet Suction.—A process of discharging material from the working chamber of a caisson by wetting it and placing it at the mouth of a discharge pipe through which it is blown by the pressure of the air.

Weyrauch's Formula.—A formula proposed by Weyrauch to determine the allowable unit stress when the member is subjected to a reversal of stress. It is no longer used in good American bridge engineering practice.

Wharf.—A structure or a level place along the bank of a waterway, upon which vessels lying alongside can discharge their cargoes.

Whatman's Paper.—See "Paper."

Wheel.—A circular framework or a solid disc capable of revolving about its centre.

Beveled Wheel.—A wheel having a sloping face.

Brake Wheel.—A heavy wheel furnished with cams to control the action of a trip hammer; the wheel of a band-brake.

Bull Wheel.—A large, horizontal wheel connected to the foot of a derrick mast for the purpose of turning the derrick with ropes leading to the hoisting engine.

Caster Wheel.—A wheel having its axle held in a stock or frame that turns about an axis perpendicular to its own.

Chain Wheel.—A wheel having projections or indentations on its face for the purpose of engaging the links of a chain.

Cog Wheel.—Same as "Gear," *q.v.*

Conical Wheel.—A wheel having a face conforming to the surface of a cone.

Crown Wheel.—A wheel with teeth set perpendicular to the plane of rotation.

Driving Wheel.—The main wheel which communicates motion to another or others.

Fly Wheel.—A heavy, revolving wheel for equalizing motion in machinery.

Friction Wheel.—A form of slip-coupling applied in cases where the variation in load is very sudden and great, as in dredges.

Gear Wheel.—See "Gear."

Hand Wheel.—A small wheel fitted to the hand for operating valves, etc.

Idle Wheel.—A wheel which runs loosely on its shaft.

Jockey Wheel.—A small wheel running against the rim of a grooved wheel to keep a rope, wire, or cable in the groove.

Joggle Wheel.—A wheel which has a wabbling motion.

Lantern Wheel.—A gear wheel composed of two parallel discs set some distance apart on an axle with round rods parallel to the axle, set at equal intervals around the periphery of the discs. These rods mesh with the teeth of another gear.

Leading Wheels.—The wheels in a locomotive placed in front of the drivers.

Pitch Wheel.—One of a pair of toothed wheels working together.

Rag Wheel.—A "Sprocket Wheel," *q.v.*

Ratchet Wheel.—A toothed wheel forming part of a ratchet mechanism. See "Ratchet."

Spoke Wheel.—A wheel having spokes instead of a solid web.

Spur Wheel.—Same as "Gear," *q.v.*

Toothed Wheel.—A wheel having teeth projecting from its face.

Traveler Wheel.—One of the wheels supporting a traveler on its track.

Unbalanced Wheel.—(Statically) Any wheel in which the centre of rotation is not coincident with the centre of gravity. (Dynamically) Any wheel in which the

[illegible]

[illegible]

Wheelbarrow.—A small hand [illegible] or box resting on two handles, [illegible] tor's hands at the other.

Wheel Base.—See "Base."

Wheel Carriage.—See "Carriage."

Wheel Chain.—See "Chain."

Wheel Concentration.—See "Concentration."

Wheel Flange.—See "Flange."

Wheel Frame.—See "Frame."

Wheel Friction.—Same as "Rolling Friction."

Wheel Guard.—See "Guard."

Wheel Load.—See "Load."

Wheel Tread.—See "Tread."

Wheel Wrench.—See "Wrench."

Whim.—An early form of windlass for hoisting.

Whetstone.—A stone for sharpening tools by

Whipple Truss.—See "Truss."

Whiskey Jack.—See "Jack."

White Iron.—See "Iron."

White Lead.—See "Lead."

White Lime.—See "Lime."

White Metal.—See "Metal."

White Pine.—See "Pine."

Wick Packing.—See "Packing."

Wide Cross-cut Saw.—See "Saw."

Wild Steel.—See "Steel."

Williot Diagram.—A graphical method for structure. See Chapter XII.

Winch.—Same as "Windlass," *q.v.*

Hand Winch.—A winch operated by hand power.

Wind Bracing.—See "Bracing."

Winding Drum.—See "Drum."

Windlass.—A winding machine consisting of an axle by a crank, a wheel, or radial bars at the end, and load to be moved.

Chinese Windlass, or Differential Windlass.—A with different diameters, so that the rope winds from the smaller, the difference between the two of a heavy load.

Spanish Windlass.—An extemporized purchase made roller and inserting a lever in a hitch or bight of the lever a considerable torsional moment is produced.

Windlass Jack.—See "Jack."

Wind Load.—See "Load."

Wind Pressure.—See "Pressure."

Wind Shake.—A crack or fissure in a piece of timber

Wind Stress.—See "Stress."

Wind Truss.—See "Truss."

Windward.—The direction from which the wind comes.

Windward Chord.—See "Chord."

Windward Truss.—See "Truss."

Abutment.—See "Abutment."

Nut.—See "Nut."

Wall.—See "Wall."

r.—Same as "Cam," *q.v.*

e Bridge.—Same as "Suspension Bridge." See "Bridge."

re Cable.—See "Cable."

re Cloth.—Wire net having a small mesh.

re Gauge.—See "Gauge."

re Iron.—See "Iron."

re Joint.—See "Joint."

re Nail.—See "Nail."

re Rope.—See "Rope."

hler's Laws.—A series of laws based on Wöhler's experiments on the fatigue of metal. It is now conceded that they do not in any way apply to bridge designing, because they deal solely with metal stressed beyond the elastic limit and are not applicable otherwise.

ood.—The hard, fibrous substance which composes the body of a tree.

Cross-fibred Wood.—A wood in which the fibres run obliquely to the axis of the tree, reversing direction in different layers and thereby producing a crossed effect.

Cross-grained Wood.—Same as "Cross-fibred Wood," *q.v.*

Curled Wood.—A wood in which the fibres are fine and run in folds or ridges, producing a curly effect in some places.

Dry Rotten Wood.—Wood subject to dry rot. See "Rot."

Hard Wood.—A term arbitrarily applied by the lumber trade to woods of the broad-leaved trees.

Heart Wood.—The older and central part of a log, usually darker than the sapwood.

Lance Wood.—A light, yellow-colored wood used in surveying rods.

Sap Wood.—The outer and lighter colored portion of a timber containing sap.

Soft Wood.—An arbitrary term for wood from coniferous trees.

ood-Boring Machine.—See "Boring Machine."

ood Screw.—See "Screw."

ork.—The overcoming of resistance through space as measured by the product of the force and the distance, in its own direction, over which it acts. Also used as a general term for any engineering construction or the operations connected with such construction.

Field Work.—Surveying and kindred operations in the field.

Herringbone Work.—Masonry work done according to the Herringbone system. See "Herringbone."

Iron Work.—Any construction using iron members.

Job Work.—Work done by the job.

Joggle Work.—Masonry construction in which the stones are internotched or keyed.

Ladder Work.—Work that is done from a ladder.

Leaf Work.—The ornamental work done on cast-iron which is sometimes used on portal bracing in bridges for appearance only; also scroll work on cast-iron columns and lamp posts.

Machine Work.—The shaping, fitting, and dressing of metal such as drilling, planing, turning, milling, and grinding done by machinery.

Mat Work.—A general term for extended mattress construction used in river protection.

Neat Work.—The work or part of construction inside of the "neat line," *q.v.*

Ornamental Work.—That portion of a structure which is added to the main portion in order to enhance its æsthetic qualities.

Pile Work.—A general term covering pile construction.

Rock Work.—Rock excavation. Also used for "Masonry," *q.v.*

[illegible]

[illegible] Drill Screw.—See "[illegible]"

[illegible]—In the [illegible] of a [illegible]

[illegible]—The art or skill of a [illegible]

Work of Friction, or Work Done in [illegible] in moving against a frictional [illegible]

Work of Resilience.—The work done by a [illegible] normal condition. Theoretically, this [illegible] during its deformation, providing that the [illegible] been passed.

Worm.—A helix or helical gear on a shaft which [illegible]

Worm Gear.—See "Gear."

Worm Rack.—See "Rack."

Worm Shaft.—See "Shaft."

Worm Wheel.—Same as "Worm Gear." See "Gear [illegible]

Worm Work Dressing.—See "Dressing."

Wrench.—A tool for turning nuts, bolts, and pipes, [illegible] jaws to fit the nut, bolt, or pipe.

Alligator Wrench.—A wrench with fixed spreading [illegible] surface, suggestive of the open mouth of an alligator [illegible]

Claw Wrench.—A wrench with a claw end.

Combination Wrench.—A wrench having jaws to fit [illegible]

Diagonal Wrench.—A wrench in which the axis of the [illegible] handle.

Double Wrench.—A wrench having a set of jaws at each [illegible]

Forked Wrench.—A wrench having a pair of jaws at one [illegible] end tapers to a point.

Key Wrench.—A socket wrench having a cross handle [illegible] sliding jaw held in place by a key.

Monkey Wrench.—A wrench having an adjustable jaw [illegible]

Open-end Wrench.—Same as "Forked Wrench," *q.v.*

Pipe Wrench.—A wrench having its jaws shaped and [illegible]

Ratchet Wrench.—A wrench provided with a handle [illegible]

Socket Wrench.—A wrench having a handle and shank [illegible] to fit the nut.

S-Wrench.—A wrench having a bent handle like the letter [illegible]

Tap Wrench.—A cross-handled wrench used for turning [illegible]

Track Wrench.—A long-handled, forked wrench, used by [illegible] nuts on rail joints.

Wheel Wrench.—A wrench having a wheel-shaped handle.

Wrench Hammer.—See "Hammer."

Wring Fit.—A fit between two parts which are so accurately [illegible] to be put together with a twisting motion.

Wrought Iron.—See "Iron."

Wrought Iron Pipe.—See "Pipe."

ught Nail.—See "Nail."

e.—A support for the telescope in the engineers' level, having the form of the Y. A railroad siding in the form of the letter Y; used for turning and trains.

X

Bracing.—See "Bracing."

Y

—An arrangement of railroad tracks, resembling the letter Y, which is used for turning trains around. Sometimes spelled "Wye."

age.—The contents or amount of material expressed in cubic yards.

w Ochre.—See "Ochre."

Point.—That point, or intensity of stress, at which the rate of stretch begins to increase rapidly.

vel.—See "Level."

Riveter.—See "Riveter."

's Modulus.—Same as the "Modulus of Elasticity." See "Elasticity."

Z

Bar.—See "Bar."

Bar Iron.—See "Iron."

Column.—See "Column."

ag Riveting.—Same as "Staggered Riveting." See "Riveting."

White.—An oxide of zinc, in the form of a white powder, which is used as a base for paint.

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Light figures refer to Volume I, bold-faced figures to Volume II